A

TREATISE

ON THE NATURE AND PROPERTIES OF

AIR,

AND OTHER

PERMANENTLY ELASTIC FLUIDS.

TO WHICH IS PREFIXED,

AN INTRODUCTION TO CHYMISTRY.

By TIBERIUS CAVALLO, F. R. S.
And MEMBER of the R. A. at *Naples*.

Aeris dotes nondum ſatis notae ſunt.—Id interim certum eſt, ad gluten pertinere, quo omnium firmorum in univerſa Natura Corporum elemta cohaerent, ut omnino, neque fere metallum, neque os, neque lapis, neque teſta, neque ſal, diſſolvatur quin aer extricatus prodeat.—*Haller Elem. Phiſiol. tom.* ii. *p.* 155.

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THIS TREATISE

ON AIR,

AND OTHER PERMANENTLY ELASTIC FLUIDS,

IS HUMBLY DEDICATED,

AS A MARK OF RESPECT,

FRIENDSHIP, AND GRATITUDE,

BY HIS

MOST OBEDIENT

AND MOST HUMBLE SERVANT,

TIBERIUS CAVALLO.

PREFACE.

THE numerous diſcoveries lately made relating to Air, and other permanently elaſtic Fluids; the ſcattered manner in which thoſe improvements had been handed to the Public; and the importance of the ſubject, ſuggeſted the idea of compiling the preſent Work, and at the ſame time afford ſome excuſe for the imperfections of the performance. The divers properties of phyſical, but inviſible ſubſtances, which can be eaſily altered, with difficulty preſerved, and with ſtill greater difficulty examined, have been often miſunderſtood, and ſometimes wilfully exaggerated. To ſelect truth, amongſt a multiplicity of aſſertions, is the difficult, though indiſpenſable duty of the Author. Each particular writer on the ſubject thinks himſelf entitled to a full diſcuſſion of his obſervations, perhaps of his errors; and the leaſt accidental or unavoidable miſtake, *is often conſtrued as the moſt illiberal miſrepreſentation of his ſentiments. Conſcious of thoſe difficulties, the Author has ſpared no pains to get information, and to repeat ſeveral experiments. He has endeavoured to take notice of every notable diſcovery and uſeful obſervation relating to his ſubject; rejecting all the inſignificant or frivolous remarks, which the leaſt ingenuity on the part of the Reader may ſuggeſt. Theſe diſcoveries and obſervations have been arranged in a methodical order, giving very little attention to the time in which they were made; ſince this book was not intended as an hiſtory of the ſubject. But it is more than probable, that, in ſpite of every effort, this Work ſtill contains many imperfections; and perhaps ſome uſeful diſcovery may have been overlooked, or improperly related. The Author, therefore, would think himſelf exceedingly obliged to any perſon, eſpecially thoſe who are converſant with the ſubject, who would make him acquainted with any new obſervation, or any imperfection of his Work; it being his earneſt deſire to render it as perfect as poſſible, in caſe of a ſecond edition.*

The Author's object has been, to acquaint a perſon, even thoſe of only a common education, with the preſent *ſtate of diſcoveries relating to Air, and other fluids ſimilar to it; he has therefore begun from the very elementary principles, which are neceſſary for the comprehenſion of the ſubject.*

In the firſt Part, under the title of An Introduction to Chymiſtry, *he has briefly deſcribed the various natural bodies, and their properties, which are neceſſary to be known before a perſon begins to examine the properties of Air and other elaſtic Fluids.*

The ſecond Part contains the principles of Hydroſtatics; the knowledge of which is neceſſary for the performance of the experiments on Air, &c.; and which, though publicly ſhewn in courſes of philoſophical lectures, and explained in many books, are, nevertheleſs, little underſtood by the commonalty of people. Here is alſo given a compendious idea of the principal properties of Air, and other permanently elaſtic Fluids, which is juſt ſufficient to qualify the beginner for the comprehenſion of the reſt of the work. This Part is concluded with the deſcription and uſe of the apparatus, and of the various methods practiſed to aſcertain the purity of reſpirable Air.

In the third Part, the known properties of all the permanently elaſtic Fluids are deſcribed at large.

The fourth Part contains ſeveral particulars relating to the ſubject; and concludes with the account of ſome experiments of the Author. Here the hypotheſes of permanently elaſtic Fluids have been but ſlightly mentioned, it being more adviſable to leave the Reader at the liberty of reaſoning by himſelf upon the aſcertained facts, than to inſiſt upon a theory, which, in this new ſubject, may to all probability be wrong, and which may retard the progreſs of farther and more diverſified inveſtigation.

Laſtly, to render the Work ſtill more intelligible and uſeful, a copious Index, and three Copper-plates, have been added to it.

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PART I.

An INTRODUCTION *to* CHYMISTRY.

CHAP. I.

Of Chymiſtry in general.

THE various bodies which exiſt upon earth, and are perceived by our ſenſes, may be divided into two claſſes, that is, *ſimple*, and *compound*; conſidering as ſimple or primary bodies, thoſe, which cannot, by any known means, be reſolved into other more ſimple ſubſtances; and underſtanding by compound bodies, thoſe which are actually reducible into, or are compoſed of other more ſimple ſubſtances. Thus pure water is conſidered as a ſimple ſubſtance, becauſe, as far as we know, it cannot be decompounded; and an animal body is called a compound, becauſe earthy particles, and various fluids, enter into its compoſition.

As almoſt all the bodies that occur to our ſenſes, and are ſubſervient to our wants, are compound ſubſtances,

whoſe

whoſe components vary both in ſpecies and quantity, according to innumerable circumſtances; it is of the utmoſt neceſſity to human kind, to inveſtigate their nature, and to find out certain means, by which a compound body may either be formed out of other more ſimple ones, or may be reſolved into its primary components. It is needleſs to expatiate upon the uſefulneſs and neceſſity of this ſubject; it being continually evinced by almoſt every operation that happens around us. Animal life, vegetation, civil and private economy, various arts and ſciences, even trade and commerce, are founded upon a continual compoſition and decompoſition of natural bodies; without which there would ſcarce be any obſervable motion upon earth.

The ſcience, which examines philoſophically the various properties of bodies, ſo as to aſcertain, by experiments and ſpeculations, the methods of effecting the divers compoſitions and decompoſitions of the ſaid bodies, is called *Chymiſtry*. In order to form a right idea of the principles of this ſcience, it is neceſſary firſt to deſcribe thoſe ſimple primary bodies or elements, by the various combinations of which the ſecond claſs of bodies is formed, and which, indeed, are the limits of Chymiſtry. The old philoſophers making uſe of ſuppoſitions rather than experiments, entertained various fanciful and often contradictory ideas relating to the elements of bodies. Epicurus thought that all bodies were modifications of one homogeneous

geneous primary element, whoſe particles were of a particular figure, ſolid, and in their nature unalterable; and that they only required to be arranged in this or that other manner, in order to compoſe the various bodies of the Univerſe. Other philoſophers thought variouſly of the number and properties of the elements; but the prevailing opinion, which has, indeed, been adopted by moſt of the writers on Chymiſtry from a long period down to the beginning of this century, was, that the elements were three, viz. Salt, Sulphur, and Mercury. The philoſophical writers, however, of the ſame time generally acknowledged four elements, viz. Air, Water, Earth, and Fire; which opinion has alſo been adopted by moſt of the late chymiſts; ſuppoſing (for they could never prove the generality of the rule by actual experiments), that every other body is compoſed out of thoſe four elements, and that it is ultimately reſolvable into them.

Conſidering the facts, and omitting the ſuppoſitions, we are obliged to enumerate a much greater number of elements than thoſe four already mentioned, or the ſeven admitted by a late ingenious writer on light. However in this Introduction we ſhall not confine ourſelves to any number of elements; it being more advantageous for the buſineſs of philoſophy, to leave their number unſettled, than to admit uncertainties for axioms.

Nature in her works proceeds uniformly from one order to the other, without limitations or diſtinctions. From the leaſt to the moſt complex body, a chain of intermediate ſteps is obſervable, which admits of no real limits or ſubdiviſions. It is the imbecillity of human underſtanding, which being unable to form any diſtinct idea of the whole, has recourſe to artificial ſyſtems, which facilitate the comprehenſion of various particulars, otherwiſe unattainable. For this reaſon, the Philoſophers who have undertaken to examine nature's works, have arranged the various bodies under diſtinct orders, as if they really had no connexion with one another. Thus they have admitted three great diviſions, called Kingdoms by the Chymiſts, that is, the Animal, the Vegetable, and the Mineral kingdom; comprehending under the firſt, all thoſe bodies which are endowed with life and ſelf-motion; calling Vegetables, all thoſe which have life only, or the power of growing, propagating the ſpecies, &c. and laſtly, conſidering under the denomination of Minerals, all thoſe bodies which are deſtitute of life and ſelf-motion. The reader, however, muſt not ſuppoſe, that thoſe orders or kingdoms ſhould be really ſeparate from one another; for there are actually many bodies enumerated amongſt the animals, which might as well be conſidered as vegetables, and many, in ſhort, which might be attributed to either of two kingdoms with ſeemingly equal propriety.

In order to give a juſt and uſeful idea of Chymiſtry to my reader, whom I muſt ſuppoſe entirely unacquainted with the ſcience, and deſirous to acquire a knowledge of it, ſo far as to underſtand the principal ſubject of this treatiſe; I ſhall in the following chapters firſt deſcribe the principal natural bodies conſidered under general heads, beginning with the moſt ſimple, and gradually proceeding to the more complicated. Next, I ſhall give an idea of chymical analyſis and compoſition; and ſhall, laſtly, conclude with deſcribing various more remarkable chymical proceſſes, by which the reader will be made acquainted with the principal artificial compounds.

But before we enter into the particular deſcription of natural bodies, it is neceſſary to obſerve, that there is a property in all ſubſtances, called by the Chymiſts *Affinity*, upon which all chymical operations depend. This is a power by which the conſtituent parts of a body unite readily with ſome ſubſtances, with which, it is therefore ſaid, that they have an affinity; and at the ſame time they ſhew a kind of repulſion to the parts of ſome other ſubſtances. Thus it is ſaid, that there is an affinity between water and vinegar, becauſe they are eaſily mixed together; and that there is no affinity between water and oil, becauſe they do not mix together, ſhewing a kind of repulſion with each other.

From this fundamental property there are deduced ſome rules, by the help of which almoſt all the phenomena obſerved in chymiſtry may be explained. Theſe rules may be reduced to the four following:

I. If two ſubſtances, which have an affinity to one another,

ther, are brought together, a compound will be formed out of them, which partakes of ſome, but not all the properties of its components; for the two bodies by their union loſe ſome of thoſe properties, which they had whilſt ſeparate, and acquire other new properties, which they had not before. Thus oil, which is inflammable, and unmiſcible with water, when combined with the aſhes of vegetables, or, more properly, with what the chymiſts call alkaline ſalts, forms the common ſoap, which is a ſubſtance miſcible with water, but not inflammable.

II. If to a body conſiſting of two ſubſtances, A and B, another ſubſtance, C, is preſented, which has affinity either with one or both the ſubſtances A and B; they will all combine together, and form a ſubſtance conſiſting of three principles. In the ſame manner a body may be formed out of four, five, or more principles. But if the body C has no affinity at all with one of the two ſubſtances, for inſtance with A, and at the ſame time has a greater affinity with B, than A and B have with each other; then a decompoſition of the firſt compound, and a new combination will enſue; for B will quit A, and will join itſelf to C, conſequently A will be left pure, and ſuch as it was before it had contracted any union with B *.

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* Notwithſtanding that the body A is ſaid to be left pure, when B and C are combined together; yet it muſt be obſerved, that often, and probably always, a ſmall portion of the ſubſtance B or C adheres to A, which is not to be detached

This is one of the moſt general and powerful means by which the chymiſt decompoſes a compound body, and finds out its components. Thus, if a metal is diſſolved in an acid, and an alkali is added to the ſolution, the acid, having a greater affinity with the alkali than with the metal, will join itſelf to the former and leave the latter, conſequently the particles of the metal, which were ſuſpended in the acid, will now fall to the bottom of the phial in which the ingredients are contained. This phenomenon is uſually called *precipitation*; hence the metal, which in this caſe is the *precipitate*, is ſaid to be *precipitated* from the acid by the alkali.

III. Sometimes a ſubſtance is incapable of decompounding a body conſiſting of two or more principles; but by being itſelf combined with ſome other ſubſtance, it forms a compoſition which can readily decompoſe that body.

IV. Laſtly, when a body, conſiſting of various principles, is preſented to another compound body, the phenomena will vary according to the affinities between the various ſimples, which enter into the compoſition of thoſe bodies, and according to the various new properties which they acquire by their combinations. Hence is derived a double compoſition and decompoſition, and an infinite

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detached from A without farther operations. The ſubſtance A may alſo have undergone ſome other hitherto unobſerved change by the proceſs; yet when ſlightly obſerved, ſeems to be the ſame as it was before the combination, and ſo far it may be called pure; although it is not ſo ſtrictly ſpeaking.

number of phenomena, which render the ſcience of Chymiſtry very difficult, and whoſe immediate cauſes often elude the moſt laborious and diligent reſearches.

CHAP. II.

Of Air, Water, Earth, and Fire.

UNDER the word *Air*, when ſignifying permanently elaſtic fluids, ſeveral ſubſtances ſhould be comprehended, which have that and various other properties in common with the air, properly ſo called, which ſurrounds every body upon earth, and conſtitutes the atmoſphere. That ſome other fluids were to be found in divers places, and obtained by various proceſſes, which had a great, though not a perfect analogy to air, was obſerved a long time ago, and particular ſpecific names were given them. But afterwards they were all called by the generic name *Air*, to which the ſpecific epithet *inflammable*, *fixable*, &c. was added. This denomination firſt aroſe from a ſuppoſition, that they were all modifications of the common reſpirable air; and they afterwards continued to be called ſo by various very modern writers, who found themſelves in a manner obliged to follow the eſtabliſhed cuſtom. At laſt a better acquaintance with the nature of thoſe fluids, owing to the wonderful diſcoveries of many ingenious philoſophers, has ſhewn the impropriety of calling them Air *. It is true that air is changeable, and by various means may acquire new properties, ſo as to appear quite different from what it was at firſt; yet there are many other fluids, which, although inviſible and permanently elaſtic like common air, are however eſſentially different from it, and, as will appear in the courſe of this work, they have ſo many peculiar and different properties, that even the moſt ſceptic philoſopher cannot heſitate to acknowledge, that they are as different from one another, and from air, as water, oil, and many other viſible fluids are. This difference renders it highly neceſſary, in order to preſerve perſpicuity, to give other names to thoſe different elaſtic fluids, and to retain the word *Air* to denote the atmoſpherical fluid; which may be defined *a fluid permanently elaſtic*, *inviſible*, *ſonorous*, *inſipid*, *inodorous*, *neceſſary for animal life*, *for vegetation*, *and various other operations*; *which conſtitutes the atmoſphere*, *and whoſe ſenſible motion is called wind.*

This fluid has generally been conſidered as a pure elementary principle; nevertheleſs, it is next to impoſſible to obtain it pure and unmixed with other bodies. It is generally mixed with a quantity of water, which may in part be ſeparated from it; beſides innumerable other ſubſtances which float in it, or are intimately mixed with its particles, which render its elementary ſimplicity merely hypothetical.

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* See the Preface to an elegant Treatiſe on the various kinds of permanently elaſtic fluids; written by the Engliſh Tranſlator of MACQUER's Dictionary of Chymiſtry.

As to the various properties of air, we ſhall here only give a general idea of thoſe which are moſt neceſſary for underſtanding this Introduction to Chymiſtry; reſerving to treat particularly of all its properties hitherto diſcovered, and the theories offered for their explanation, in other parts of this work; where we ſhall examine the nature of Air, its origin, the changes it undergoes in natural or artificial proceſſes, the methods proper to aſcertain the degree of its purity, and various other particulars, not only remarkable for their uſe in farther philoſophical reſearches, but exceedingly intereſting to human kind in general.

That the air is ponderous, like all other bodies, may be aſcertained by various means, which not only point out its exact gravity in different temperatures, but ſhow that a vaſt weight continually preſſes upon our bodies, and, in ſhort, upon the whole ſurface of the earth. It is always a fluid, at leaſt it was never obſerved to be condenſed into a compact ſolid form, either by cold or by any other means whatſoever. But this obſervation does not prove that fluidity is abſolutely eſſential to air; it appearing not impoſſible, that a greater degree of cold, than has been hitherto obſerved, or ſome other method, may condenſe it into a ſolid form. Cold, although it never was obſerved to condenſe air into a ſolid, does however contract it, as it contracts every other ſubſtance; and, on the contrary, heat rarefies it. The heat of boiling water, which is equal to the 212th degree of Fahrenheit's thermometer, or the 80th of Reaumur's, expands air one third; and the heat of iron quite red hot, or beginning to be white, expands it to about four times its own bulk *. Air may alſo be rarefied, and condenſed infinitely more by mechanical means. But the moſt ſingular properties of air, which indeed are the moſt intereſting to Chymiſtry, are its power of aſſiſting the evaporation of volatile matters, and its being abſolutely neceſſary for the combuſtion of burning bodies. Not only the preſence of air is neceſſary to combuſtion, but there is required a continual change of it; for the ſame air cannot aſſiſt the combuſtion of a burning body, for inſtance of a candle, longer than a time, which is proportionate to its quantity, purity, and to the ſize of the flame of the candle; after which time a ſupply of freſh air is required in order to keep the candle burning. As combuſtion requires a continual ſupply of freſh air, ſo it is much facilitated by a quick change of it; hence is derived the uſe of bellows, which, by changing the air very often, increaſe the fire prodigiouſly.

Next to the Air we ſhall conſider Water; which is a ſub-

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* See ROBINS's New Principles of Gunnery, Chap. I.

ſubſtance ſo well known, that it hardly requires to be defined. The want of taſte, ſmell, and colour, is the eſſential characteriſtic of pure water; indeed ſo certain, that it is a ſure ſign of its impurity, when the leaſt ſmell, taſte, or colour can be perceived in it. As for its fluidity, it may be conſidered as accidental; it being well known that water becomes a ſolid, called *ice*, when its degree of heat is equal, or leſs than the 32d degree of Fahrenheit's thermometer. It is a remarkable property of water, that it cannot acquire a degree of heat greater than that required to make it boil, which is equal to the 212th degree of Fahrenheit's thermometer, excepting when it is confined in cloſe veſſels, or otherwiſe preſſed; for then it can acquire a much greater degree of heat, even ſufficient to make it red hot, as it is ſaid. But when kept in an open veſſel, under the ſame preſſure, it always boils at the ſame degree of heat; after which, a ſtronger fire will only make it evaporate ſooner, without communicating to it a greater degree of heat. The vapour which ariſes from water is only water reduced into an elaſtic fluid, which is compreſſible, elaſtic, &c. but it is not permanently ſo; for by a ſufficient preſſure, or by a ſmall degree of cold, it is again reduced into that ſelf-ſame water from which it originated. Hence we ſee the difference between the vapour of water, and air. It is this property only which diſtinguiſhes all thoſe elaſtic fluids called *vapours*, from thoſe called *permanently* elaſtic; namely, that the former may be actually reduced into a viſible form, ſimilar to that of water, by cold, or by a ſufficient preſſure, whereas the latter cannot.

The aſſerting, that the vapour of water is only water reduced into an elaſtic fluid, implies, that water is not elaſtic, or not compreſſible; but this is not true ſtrictly ſpeaking, becauſe water has been found to be compreſſible in a ſmall degree *. However, as its compreſſibility hitherto obſerved is ſo exceedingly ſmall, that it ſcarcely amounts to the one or two hundred thouſandth part of its bulk, we may ſafely conſider it as incompreſſible.

Water diſſolves various bodies, as gums, ardent ſpirits, all ſaline ſubſtances, various ſpecies of earth, divers metals, and even a ſmall portion of common air; beſides its abſorbing a prodigious quantity of other permanently elaſtic fluids, as will be particularly mentioned hereafter. In conſequence of this property, it follows, that to get water perfectly pure is ſo very difficult, that it may be conſidered as almoſt impoſſible. The water eſpecially of rivers and ſprings, is ſo very full of heterogeneous matters, that ſometimes it is quite uſeleſs, not only for nice chymical operations, but alſo for economical purpoſes, except it is firſt purified by diſtillation, filtration, boiling, and other means. It is owing to theſe extraneous matters, which the water keeps diſſolved, that it acquires various properties, and becomes chalybeate, ſulphureous, ſalt, petri-

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* See the Philoſoph. Tranſ. vol. LIV.

fying, poiſonous, incapable of diſſolving ſoap, &c. In thoſe caſes, it is the buſineſs of Chymiſtry to analyze the water, in order to aſcertain the heterogeneous ſubſtances it contains, and the uſes to which it may be applied. As water diſſolves ſundry matters, ſo does itſelf combine and enter into the compoſition of various bodies, as ſalts, oils, ſtones, vegetables, and other ſubſtances, excepting metals, and thoſe bodies called by the mineralogiſts *vitrifiable ſtones*; for by any experiment hitherto made, no water could be obtained from them. Water has been generally conſidered as a ſubſtance *ſui generis*, pure and elementary, notwithſtanding various ingenious perſons have aſſerted, that it may be changed into other ſubſtances, eſpecially into earth. This aſſertion has been founded principally upon the reſult of various experiments, which ſhew, that when water, as pure as can be got, has been repeatedly diſtilled, or otherwiſe treated, in proper veſſels, it generally leaves a quantity of earth at the bottom of the veſſels. It would be endleſs to relate the various diſputes which have originated from thoſe experiments, and the labour that the experiments themſelves have coſt to ſeveral ingenious philoſophers. It will be ſufficient for our preſent purpoſe to mention, that the moſt deciſive experiments as yet made ſeem to ſhew, that the earth thus found in the veſſels, wherein water has been diſtilled, or otherwiſe treated, is either an extraneous matter, not to be ſeparated from the water, without long operations, or that it is a matter abraded from the veſſels by the joint action of water and fire. The growing of plants in veſſels containing nothing but water, has alſo been alledged as a convincing proof of the convertibility of water into other ſubſtances, or, as ſome perſons fancifully ſtyle it, into *vegetable earth*. This experiment is, however, of not the leaſt weight; it being eaſy to comprehend, that as earthy, ſaline, and innumerable other particles continually float in the air; the water expoſed to it, although previouſly purified, will eaſily imbibe them, and thus be able to furniſh matter for the vegetation of plants. It may therefore be concluded, that as no deciſive experiment has hitherto demonſtrated, that water is convertible into any other ſubſtance, or any other ſubſtance is convertible into water; we may conſider it as a prime elementary principle; by which we imply not an impoſſibility of altering the nature of water, but only acknowledge our incapacity of effecting it at preſent.

Pure Earth has alſo been conſidered as an element unalterable, and *ſui generis*; nay, ſome philoſophers have even conſidered it as the only original element, out of which all the other ſubſtances were derived. Nevertheleſs, experimental philoſophy, in oppoſition to fancy and opinion, ſhews that this ſuppoſed original element has the leaſt right to be conſidered as ſuch; it being almoſt impoſſible to get two ſpecimens of this pure earth that are perfectly alike. When Chymiſts analyze any ſubſtance,

ſtance, they conſtantly find at the end of the proceſs a quantity of earth, upon which they can work no longer; becauſe it remains fixed and unalterable in the ſtrongeſt fire they can produce, &c. But if it be conſidered, that there are various ſorts of earth endowed with the ſame properties of reſiſting the action of fire, &c. which, however, are not changeable into one another, on account of various other properties peculiar to each of them; we ſhall then be obliged to abandon the notion of ſuch an original element, and to take a ſeparate view of the properties belonging to each body, comprehended under the generic name *Earth*, when taken in the popular ſenſe.

Fire is the other element of the Chymiſts; whoſe nature has occaſioned innumerable controverſies, and which, whilſt it is one of the greateſt agents of nature, is at the ſame time very little underſtood. To mention only a few of the principal hypotheſes relating to it, with their various explanations and objections, would be involving my reader in a labyrinth of philoſophical perplexities, as ill adapted to the minds of novices, as they are foreign to the main ſubject of this book. In order to give an uſeful idea of its nature and properties, it is neceſſary to obſerve, that by the word *Fire*, in common language, we underſtand not a ſimple ſubſtance, but a complex idea of ſomething red, ſhining, which excites our ſenſation of heat, and rarefies all known bodies: now it is the cauſe of thoſe effects that philoſophers mean, under the appellation of fire conſidered as an element. The great point in queſtion is, whether this cauſe is real matter, whoſe eſcape from burning bodies produces the above-mentioned effects, or is a particular agitation of the particles of burning bodies. Both ſides of the queſtion have been defended by very reſpectable perſons in the philoſophical world, but without coming to any deciſion ſupported by concluſive experiments. The matter of fact is, that every known body is capable of becoming hot, either by the approach of ignited bodies, or by friction and other means; but every body is not capable of producing fire, that is, of being inflamed. Thus aſhes may be made very hot, but they cannot be made to burn like charcoal and other ſubſtances, which are therefore called inflammable bodies. However, inflammability is not the property of ſome bodies ariſing from their very nature, or from a particular arrangement of their conſtituent particles, but is the property of a particular ſubſtance, called *Phlogiſton*, which, when combined with various ſubſtances in due proportion, renders them inflammable. This phlogiſton cannot be obtained pure and unmixed with other ſubſtances; but by divers methods it may be ſeparated from a body and given to another; hence an inflammable body may be deprived of its inflammability, and a body naturally not inflammable, may be rendered inflammable by combining it with a ſufficient quantity of phlogiſton. This inflammable

mable principle, whether the effects of fire are attributed to its actual violent eſcape from the burning ſubſtances, and propagation among the ſurrounding bodies, or to a particular agitation of its particles, ſeems to be in its nature indeſtructible; becauſe, when a body is burning, the phlogiſton, which eſcapes from it, is not annihilated, or converted into ſomething elſe, but is only communicated to the air, or other ſurrounding bodies, which give indiſputable proofs of having acquired it, or, as it is commonly ſaid, of being *phlogiſticated.* This fact is ſo true and general, that a body cannot burn where there are no ſubſtances ready to imbibe the phlogiſton that eſcapes from it; hence a piece of charcoal cannot be made to burn in water, becauſe water does not combine but with a ſmall portion of phlogiſton, not to be compared to the great quantity of it, which comes out of the charcoal whilſt burning. But in air the charcoal, or any other combuſtible body, burns very well, becauſe the air eaſily combines with phlogiſton; yet when the air ſurrounding the burning body has acquired as great a quantity of phlogiſton as it can contain, it becomes unfit to aſſiſt the combuſtion any longer; conſequently, the fire will be extinguiſhed, except the air be changed. From this it appears why the wind, that is a continual change of air, promotes combuſtion, and alſo why a fire will not burn well where the air is in ſome meaſure phlogiſticated, and why the fire is put out when the air, which has once ſerved to combuſtion, is blown upon it through a pipe or otherwiſe.

Phlogiſton, or the inflammable principle, has a great affinity with ſome bodies, and a very ſlight one with others; but it ſeems that a ſmall ſhare of it is combined with every ſubſtance that falls under our obſervation; which ſmall quantity of phlogiſton is ſo very difficult to be ſeparated from thoſe matters, that, perhaps, there was never any ſubſtance obſerved, but contained ſome quantity of it.

To explain the effects of fire is the greateſt difficulty in this ſubject, and which indeed ſeems as yet to elude all philoſophical inveſtigations. Fire, or combuſtion, produces heat, rarefaction, and light. A ſufficient quantity of light, as the rays of the ſun collected into a ſmall ſpace by a burning-glaſs, produces heat ſufficient to make combuſtible bodies burn; and independent of light, a ſufficient quantity of heat produced by friction, and other means, occaſions combuſtible bodies to burn; yet it is difficult to aſſert, whether phlogiſton, either in motion or in a quieſcent ſtate, light, and heat, are the ſame ſubſtance, or different principles, which act upon each other alternately, and according to various circumſtances one or more of them becomes manifeſt to our ſenſes.—Referring thoſe of my readers, who are deſirous of examining particularly what has been ſaid on light, to the works of other authors, who have written expreſsly upon that ſubject; I ſhall conclude this chapter with mentioning an ingenious hypotheſis on heat and combuſtion, lately publiſhed by Mr. Crawford, in his ingenious Treatiſe on Animal Heat.

By that hypotheſis heat is conſidered as a principle *ſui generis*, diſtinct from phlogiſton, and diſperſed throughout the bodies of the univerſe, according to their various capacities of containing it; for ſome bodies are capable of containing a greater quantity of it, than others of the ſame bulk, or of the ſame ſpecific gravity. When this natural diſperſion of heat is diſturbed, ſo that ſome bodies are made to part with ſome of their natural quantity of it; and others are made to acquire it, then a *ſenſible heat* is produced, viz. the bodies which have acquired a ſuperfluous quantity of elementary heat, become ſenſibly hot, ſo as to be expanded, to expand other contiguous bodies, &c. and by gradually communicating their ſuperfluous heat to the ſurrounding bodies, endeavour to return to their natural ſtate; whilſt thoſe bodies which have loſt part of their natural heat, become ſenſibly cold, and, in order to reſtore the equilibrium, attract part of the heat belonging to the ſurrounding ſubſtances, till they become all of the ſame temperature. It is further advanced, with the ſupport of very nice experiments, that generally thoſe bodies, which contain a great quantity of phlogiſton, have but a ſmall quantity of elementary heat; and, on the contrary, that thoſe bodies which have the leaſt quantity of phlo giſton, contain the greateſt ſhare of elementary heat; from which principle it follows, that when a body acquires an additional quantity of phlogiſton from another body, it loſes at the ſame time a quantity of its elementary heat, which heat is communicated to the ſubſtance that has loſt the phlogiſton, and to the ſurrounding bodies. Now in combuſtion, whilſt the burning body is continually loſing its phlogiſton, the ſurrounding air imbibes it; but by acquiring this additional quantity of phlogiſton, the air's capacity of containing elementary heat is diminiſhed, and at the ſame time the capacity of the burning body is augmented by the loſs of the phlogiſton; therefore it follows, that the air muſt depoſit its elementaay heat upon the burning ſubſtance, and other contiguous bodies, which accordingly become ſenſibly hot. Hence may be explained why a combuſtible body is cauſed to burn by making it very hot; for in proportion as the body acquires a ſuperfluous quantity of heat, its capacity of containing phlogiſton is leſſened, conſequently the phlogiſton eſcapes from that body, and occaſions the combuſtion. Mr. CRAWFORD relates a great number of experiments and natural proceſſes, which he explains by the ſaid hypotheſis; which ſeems to be very ſatisfactory, and may be ſeen at large in the above-mentioned Treatiſe on Animal Heat.

CHAP. III.

Of Acids.

ACIDS are ſuch ſubſtances, either in a liquid or concrete form, which have a ſour taſte like vinegar, verjuice, &c. They are extracted from various bodies, as well mineral as vegetable or animal; on which account they are diſtinguiſhed into Mineral, Vegetable, and Animal Acids. The acids of the firſt claſs are three, viz. The Vitriolic, the Nitrous, and the Marine acid. The principal vegetable acids are the Acetous, the Vinous acid or tartar, the eſſential acid of vegetables, and the acid obtained from oils and reſins. The Animal acids are principally the Phoſphoric, the acid of ants and other inſects, and the acids of healthy and diſeaſed ſtomachs of animals. Beſides theſe, there are a few more acids known, like that extracted from borax, the acid of bitumens, &c. and probably there are ſeveral others unknown. As the acids moſtly uſed in chymiſtry, and other branches of philoſophy, are thoſe extracted from minerals, we ſhall take particular notice of them in this chapter, and ſhall reſerve to ſpeak of the others when we are examining the ſubſtances from which they are obtained. But firſt it is neceſſary to mention thoſe properties, which belong to all the acids in general, by which they are diſtinguiſhed from the other claſſes of bodies.

I. All acids have a great affinity to water, with which they combine ſo very eaſily, that moſt of them generally appear in a liquid form, on account of the great quantity of water with which they are mixed. II. They may be combined with ſpirit of wine. III. With abſorbent earths. IV. With alkalis. V. They may be combined with metallic ſubſtances; but every acid cannot be combined with every metal indiſcriminately. VI. When they are much concentrated, that is, free from a good deal of water, they may be alſo combined with phlogiſton and oils.

The principal effects ariſing from their various combinations, are the following. I. When concentrated acids are properly mixed with ice or ſnow, they produce cold. Indeed ſo great a degree of it has been produced by this means, that even quickſilver has been frozen by it. II. They ſoften and diſſolve ſolid animal ſubſtances. III. They coagulate moſt of the animal fluids. IV. They change to red the blue, and heighten the red colours of many vegetables, excepting the volatile ſulphureous acid, which deſtroys theſe colours. From this property is derived a method of diſcovering the preſence of an acid in any ſubſtance, when its quantity is ſo ſmall that it cannot be diſtinguiſhed by the acid or pungent taſte common to acids. The practical method is, to put part of the ſubſtance to be tried into the tincture of heliotropium, or other vegetable infuſion of a blue colour, and to agitate the mixture, which will ſoon aſſume a red colour if the ſubſtance tried does really contain any acid uncombined. V. They reſiſt fermentation. VI. They require a greater degree of cold than water in order to freeze. VII. Laſtly, when they are combined with various of the above-mentioned ſubſtances, they expel from them, or for ſome other reaſon produce various elaſtic fluids; but this property will be particularly examined hereafter.

Beſides the above-mentioned, every acid has ſome peculiar properties, by which they are diſtinguiſhed from one another; and even ſome or all the above-mentioned properties are poſſeſſed by one acid in a more eminent degree than by another. It has been the opinion of many excellent chymiſts, that various of the above-enumerated acids are only modifications of a few; or rather, that they are all modifications of one primary acid, which acquires different properties according to the different ſubſtances with which it is combined, and forms the other acids. From whence it follows, that by proper means one acid might be changed into another; but this tranſmutation of acids, although attempted by many induſtrious chymiſts, I do not know that it has ever ſucceeded.

The acid of vitriol, commonly, though improperly, called oil of vitriol in the ſhops, is a fluid, tranſparent, colourleſs, and inodorous like water, but much heavier and leſs volatile than water; hence by diſtillation the water may be ſo far ſeparated from it, that the acid aſſumes a ſolid form, in which ſtate it is called the *glacial* or *icy* oil of vitriol. When this acid is expoſed to the air, it attracts the water from it, in cenſequence of which its bulk is conſiderably increaſed, and its activity is weakened. As this acid is ſeldom found ſimple in nature, there are various means practiſed to extract it from thoſe minerals, which contain a great quantity of it. Theſe minerals are principally ſulphur and vitriols, from which the vitriolic acid is eaſily extracted by burning, or otherwiſe decompoſing them. The vitriolic is the ſtrongeſt acid hitherto diſcovered; its power of diſſolving compounds, and combining with ſundry ſubſtances, being upon the whole ſtronger than that of any other acid. The following liſt contains the ſubſtances with which the vitriolic acid has any affinity, beginning with thoſe with which it has the ſtrongeſt affinity, and ending with thoſe which it ſeems to have the leaſt affinity with *.

N. B. Theſe ſubſtances will be properly defined in their proper places.

1. Pure ponderous earth,
2. Fixed vegetable alkalies,
3. Fixed mineral alkalies,
4. Pure lime,
5. Pure magneſia,
6. Volatile alkali,
7. Zinc,
8. Iron,
9. Lead,
10. Tin,
11. Cobalt,
12. Copper,

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* This rule in arranging the ſubſtances, which have affinity with a given body, is followed in all the liſts of affinities throughout this Introduction.

13. Nickel,
14. Arſenic,
15. Biſmuth,
16. Quickſilver,
17. Antimony,
18. Silver,
19. Gold,
20. Platina,
21. Argillaceous earths,
22. Calx of iron,
23. Water, and
24. Phlogiſton.

The nitrous acid comes next to the vitriolic, in point of ſtrength and ſpecific gravity; its weight being to that of water as 19 to 12; whereas the weight of very concentrated vitriolic acid is more than double the weight of water. The nitrous acid, which is alſo called *aqua fortis* by the artiſts, from its power of readily diſſolving moſt metals, is extracted by diſtillation from a ſalt called *nitre*, or *ſalt-petre*, from which the acid evidently derives its more uſual name. This acid being leſs fixed than the vitriolic, cannot be ſo much concentrated as to aſſume a ſolid form, except when it is combined with ſome other ſubſtance. It is therefore always a fluid, which generally appears of a yellowiſh red colour, and is continually exhaling in vapours of the ſame colour as itſelf, which have a peculiar ſtrong ſmell. It muſt, however, be obſerved, in regard to the uſual colour of this acid, that by expoſure to the open air it becomes colourleſs, and at the ſame time acquires an addition to its bulk by extracting the water from the atmoſphere, which this acid does in a conſiderable degree, though not ſo ſtrongly as the vitriolic.

Indeed, by being diluted it generally loſes its colour; but even when much concentrated, the yellowiſh red colour has been lately diſcovered by Dr. PRIESTLY to be not eſſential to it; the Doctor having found out a method by which the colour of this acid may be changed, taken away, or given to it at pleaſure. "The facts," ſays he, "that I ſhall relate, prove that it is either *phlogiſton*, or "*mere heat*, that gives colour to this acid; that this colour "may alſo be all expelled by heat; but that continuance "of heat will give it more colour, and deepen it at plea"ſure; ſo that more heat, in glaſs veſſels hermetically "ſealed, ſeems to have the ſame effect with phlogiſton. "But more probably, heat affects it in ſuch a manner, as "to develope, as it were, the phlogiſton it contained be"fore, and put it into *a new ſtate*, rendering that part of "the acid to which it is attached both more volatile, and "alſo diſpoſed to reflect the rays of light in a particular "manner; whereas, before this action of the heat, the "phlogiſton was *latent*, at leaſt did not evidence itſelf by "thoſe particular effects*."

The following liſt exhibits the ſubſtances with which the nitrous acid has an affinity, according to Profeſſor BERGMAN's table of affinities, publiſhed in the ſecond volume of the *Nova acta ſocietatis ſcient. Upſalienſis*; from which all the liſts of affinities given in this Introduction to Chymiſtry, are principally taken.

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* See Dr. PRIESTLY's Experiments and Obſervations relating to various Branches of Natural Philoſophy, with a Continuation of the Obſervations on Air, which makes the 4th volume of his Experiments on Air. Sect. I.

1. Pure ponderous earth,
2. Fixed vegetable alkali,
3. Fixed mineral alkali,
4. Pure lime,
5. Pure magneſia,
6. Volatile alkali,
7. Zinc,
8. Iron,
9. Lead,
10. Tin,
11. Cobalt,
12. Copper,
13. Nickel,
14. Arſenic,
15. Biſmuth,
16. Mercury,
17. Antimony,
18. Silver,
19. Gold,
20. Platina,
21. Pure argillaceous earth,
22. Water, and
23. Phlogiſton.

According to ſome Chymiſts, the nitrous as well as the vitriolic acid is ſaid to have a ſtronger affinity with phlogiſton than with any of the metals, or any other ſubſtance whatever.

The third mineral acid is the marine, ſo called becauſe it is extracted from ſea-ſalt, or other ſalts of the ſame kind, though of different origin, as the foſſil ſalt, the ſalt of fountains and pits, &c. This acid ſeems to participate of the natures of both the vitriolic, and the nitrous. It is ſcarce ever concentrated as much as the other two acids, by reaſon of its being much more volatile than either; hence it is always a fluid, except when combined with other ſubſtances. Its uſual colour is more yellow, and leſs red, than the nitrous acid; yet Dr. Priestly has diſcovered, that this colour is neither eſſential to it, nor is owing to phlogiſtic matter combined with it; but that it is owing to ſome impregnation, generally, if not always, of ſome earthy matter, with which, it is well known, that this acid unites much more readily than the others; and that by ſeparating the earthy matter from the coloured marine acid, it may be rendered quite colourleſs and tranſparent like water *.

The ſmell of marine acid is much like ſaffron. It is a particular property of this acid, to diſſolve metallic matters with leſs heat and efferveſence, and with fewer vapours than the nitrous acid; and alſo to render thoſe metallic ſolutions in great meaſure volatile, ſo as to be capable of being ſublimed or diſtilled along with it.

The following liſt contains the various ſubſtances, with which this acid has any affinity:

1. Pure ponderous earth,
2. Fixed vegetable alkali,
3. Fixed mineral alkali,
4. Pure lime,
5. Pure magneſia,
6. Volatile alkali
7. Zinc,
8. Iron,
9. Lead,
10. Tin,

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* See Dr. Priestly's Experiments and Obſervations on Air, Vol. IV. Sect. VIII.

11. Cobalt,
12. Copper,
13. Nickel,
14. Arſenic,
15. Biſmuth,
16. Mercury,
17. Antimony,
18. Silver,
19. Gold,
20. Platina,
21. Pure argillaceous earth,
22. Calx of iron,
23. Water, and
24. Phlogiſton.

As the above-mentioned acids, eſpecially ſuch as they are bought at the ſhops, are ſeldom or never pure; their properties vary, though not in a very great degree, according to the heterogeneous ſubſtances with which they happen to be combined.

It is alſo neceſſary to be remarked, that notwithſtanding various ſubſtances are ſet in the liſts of the affinities of thoſe acids; yet the acids have no power of acting upon ſome of them, except they are aided by fire, or two acids are combined together. Thus either the marine or nitrous acid are incapable of diſſolving gold; but when mixed together they form a compound menſtruum, called *aqua regia*, which can readily diſſolve gold, and platina.

When any of the ſaid acids are mixed with water, a heat is produced, which is greater or leſs, in proportion to the ſtrength and quantity of the acid employed. When about two ounces of much concentrated vitriolic acid is mixed with an equal quantity of pure water, it occaſions a ſudden ebullition, and a noiſe ſimilar to that produced by a red-hot iron plunged into water.

CHAP. IV.

Of Alkalies.

PREVIOUS to the deſcription of Alkalies, it is neceſſary to mention what the Chymiſts mean by the denomination of ſalts, the various ſpecies of which will be conſidered in the next chapter. Thoſe bodies are called ſalts, or ſaline ſubſtances, which are ſoluble in water, affect the ſenſe of taſte, and in regard to gravity and fixity are generally in an intermediate degree between the moſt pure earth and water. It is of no conſequence whether the taſte of a body is like that of the ſalt commonly uſed in the kitchen or not; but if it has any taſte at all, and is ſoluble in water; in ſhort, if it ſtrictly anſwers the definition given above, it is conſidered as a ſalt. This I do remark particularly, becauſe many perſons, not acquainted with the language of Chymiſtry, can hardly be reconciled to call ſugar a ſalt; by which they are uſed to underſtand the common ſalt, which, by its diſpleaſing taſte when by itſelf, is rather conſidered as diametrically oppoſite to ſugar. By the definition it appears, that the number of ſaline ſubſtances muſt be very great; indeed it comprehends ſuch a variety of bodies, that they are far from being all ſufficiently known, and render the word ſalt a very vague and too general a name. There are various ſubſtances conſidered as ſalts, which in reality contain but a ſmall portion of a really ſaline ſubſtance, combined with ſome other matter of a quite different nature.

Now Alkalies, or Alkaline ſubſtances, are ſaline bodies, diſtinguiſhed from other kinds of bodies by all the following properties. I. They combine with acids more readily than any other known ſubſtance, excepting the pure ponderous earth, occaſioning an effervescence and heat. II. When they are in a concrete form, into which they may be eaſily reduced by evaporation, if expoſed to the open air, they attract the moiſture from it, though not ſo ſtrongly as concentrated acids, and generally *deliqueate*, that is, become a fluid. But if they are mixed with water all at once, a conſiderable degree of heat is produced. III. They generally change the blue and red colour of vegetables to a green, whereas the acids change it to red, or to a ſtronger red. IV. They have an acrid burning taſte, which has ſomething of urinous. V. They partly exhale with water, eſpecially when boiled in open veſſels. VI. They may be fuſed by a moderate heat; and in that ſtate they diſſolve all ſorts of earths, eſpecially thoſe called vitrifiable; and if the heat is ſufficient, they and the earth form a brittle ſubſtance,

called

called *glaſs*; and upon this principle common glaſs is made.

Alkalies are principally diſtinguiſhed into *fixed* and *volatile*; the former being not ſo eaſily diſſipated even by a ſtrong fire; for which reaſon they are commonly employed in making glaſs, and other compoſitions. But the volatile alkalies are ſo eaſily diſſipated, that they may be almoſt entirely evaporated by a much leſs degree of heat than that of boiling water. Notwithſtanding that various ſorts of alkali are enumerated, it is ſuppoſed that there is but one alkaline principle in nature, which, by being variouſly combined with ſundry ſubſtances, aſſumes various particular properties. However, an alkali is never found pure in nature, but it is always combined with other ſubſtances, from which it muſt be ſeparated by art, in order to obtain it ſufficiently pure. The fixed alkali is obtained either from ſea-ſalt, or from vegetables; hence it is called *fixed mineral alkali* in the firſt caſe, and *fixed vegetable alkali* in the ſecond. The volatile alkali is obtained, by means of decompoſition and putrefaction, from all animal ſubſtances, and may be alſo obtained by decompoſition, and other means, from ſome vegetable and a few other matters. Fixed alkali, whether vegetable or mineral, has always the ſame principal properties; yet they differ from one another in degree, viz. the mineral alkali poſſeſſes the alkaline properties in a leſs degree than the vegetable alkali; for when it is expoſed to the open air, it will not attract the moiſture from it in ſuch a quantity as to deliqueate; when mixed with water it will not occaſion ſo much heat as the fixed vegetable alkali, &c.—Its affinity with other ſubſtances is exhibited below:

1. Vitriolic acid,
2. Nitrous acid,
3. Marine acid,
4. Phoſphoric acid,
5. Acid of ſugar,
6. Other vegetable acids,
7. Sulphur,
8. Oils,
9. Tin,
10. Lead,
11. Copper,
12. Gold, and
13. Water.

The fixed vegetable alkali has an affinity with the following ſubſtances:

1. Vitriolic acid,
2. Nitrous acid,
3. Marine acid,
4. Phoſphoric acid,
5. The acid of ſugar,
6. Other vegetable acids,
7. Sulphur,
8. Oils,
9. Tin,
10. Lead,
11. Copper,
12. Gold, and
13. Water.

Alkaline ſalts are of great uſe in Chymiſtry, not only becauſe they counteract the action of acids, but alſo becauſe they are powerful ſolvents; and when combined with other ſubſtances, communicate to them part of their ſaline properties. Thus when they are combined with ſulphur, they make a compound called *hepar ſulphuris*, or *liver of ſulphur*, which is diſſoluble in water, whereas ſulphur by itſelf is not; and when they are combined with oils, form compounds called *ſoaps*, which are diſſolvable in water, whereas oil by itſelf is not. The fixed alkali, more commonly uſed, by reaſon of its greateſt purity, is that extracted from tartar, which is a ſubſtance found adhering to the ſides of caſks that have contained wine, and is conſidered as the eſſential ſalt of that liquor. This alkali, when it is in a liquid form, by its combination with a ſufficient quantity of water, is commonly, but improperly, called *oil of tartar*.

Volatile alkali, when firſt extracted from animal or vegetable ſubſtances, is very impure, but by proper methods it may be purified to a great degree; and in that purified ſtate it differs from fixed alkali, principally becauſe it is very volatile, and it has a ſtrong penetrating ſmell, which occaſions coughs, ſuffocation, &c.—The hart's-horn drops commonly uſed, the ſmell of which almoſt every body knows, are a volatile alkali.

The volatile alkali has an affinity with the following ſubſtances:

1. Vitriolic acid,
2. Nitrous acid,
3. Marine acid,
4. The acid of ſugar,

5. Other vegetable acids,
6. Sulphur,
7. Oils,
8. Zinc,
9. Tin,
10. Cobalt,
11. Copper,
12. Nickel,
13. Biſmuth,
14. Silver,
15. Gold, and
16. Water.

CHAP. V.

Of Salts.

FROM the definitions of Salts, or Saline ſubſtances, given in the preceding chapter, it appears, not only that their number is very unlimited, but alſo that they are compound bodies. Acids and alkalies, and combinations of both, when in a concrete form, are ſalts, and of the pureſt ſort. The bodies therefore to which the name of ſalts more properly belongs, are the concretions of thoſe ſubſtances, which are accordingly called *acid ſalts*, *alkaline ſalts*, and *neutral ſalts*; which laſt are combinations of acid and alkaline ſalts, in ſuch proportion as to render the compounds neither ſour nor alkaline to the taſte. This proportionate combination is called *ſaturation:* thus the common kitchen ſalt is a neutral ſalt, compoſed of marine acid and mineral alkali combined together to the point of *ſaturation*. The appellation of neutral ſalts is alſo extended to denote all thoſe combinations of acids, and any other ſubſtance, with which they can unite ſo as to loſe, wholly or in great meaſure, their acid properties.

Notwithſtanding that the general definition of ſalts given above is commonly received, yet there are many writers, eſpecially mineralogiſts, who confine the denomination of ſalts to thoſe ſubſtances only, which, beſides the general properties of ſalts, have the power of *cryſtallizing*, that is, of arranging their particles ſo as to form regularly-ſhaped bodies, called *cryſtals*; when the water ſuperfluous to their concrete exiſtence has been evaporated.

Salts of various ſorts are found already formed in nature, but a great many others are made by art, and even ſeveral of the natural ones may be imitated. In this chapter we ſhall conſider thoſe ſalts only, either natural or artificial, which are moſtly uſed, and are neceſſary to underſtand the following treatiſe.

The vitriolic acid, when combined with other ſubſtances, forms vitriolic ſalts, which vary both in ſpecific names and properties, according to the various ſubſtances with which the acid is combined. Thus the vitriolic acid, combined with mineral alkali, forms the ſalt called *Glauber's ſalt*, or *ſal mirabile.* When it is combined with calcareous earths, it forms vitriolic ſalts with baſes of calcareous earth, which are commonly called *ſalenites*. When combined

bined with argillaceous earths, it forms *alum.* When combined with metals, it forms vitriolic ſalts with metallic baſes, to which the general name *Vitriols* is given; and in commerce are commonly called *copperas.* The vitriols principally uſed are, 1. The *martial vitriol*; called alſo *Engliſh vitriol*, *green vitriol*, or *green copperas*, which is a combination of vitriolic acid with iron. 2. The vitriol of copper, called alſo *blue vitriol*, *Cyprian vitriol*, or *blue copperas*; which is a combination of vitriolic acid and copper. 3. The vitriol of zinc, called alſo *white copperas*, and *Goſlar vitriol*; which is a combination of the ſame acid with a ſemi-metal, called *zinc.* It is a property peculiar to the vitriolic acid, that all the combinations of it, with thoſe ſubſtances with which it can form neutral ſalts, are ſuſceptible of cryſtallization.

The nitrous acid, combined with all the ſubſtances, with which it can mix, forms ſaline ſubſtances, in general called *nitrous ſalts*; ſpecifying each particular ſalt by the name of the ſubſtance united to the acid. Thus nitrous acid, with fixed vegetable alkali, forms a ſaline ſubſtance called *nitre*, or *ſaltpetre.* With mineral alkali, forms *cubic* or *quadrangular nitre.* When mixed with metallic ſubſtances, forms metallic nitres, which are ſpecified *nitre* of *gold*; *nitre* of *ſilver*, or *lunar* nitre, *lunar cryſtals*, and *cryſtals* of *ſilver*; *nitrous cryſtals of mercury*; *nitre of copper*, &c.

The marine acid, combined with various matters, forms marine *ſalts*, or ſimply *ſalts*, ſpecified by the names of their particular baſes. The *ſea-ſalt*, or *kitchen-ſalt*, and *ſal gem*, are combinations of marine acid and mineral alkali. When this acid is combined with volatile alkali, it forms *ſal ammoniac* *. With metals it forms metallic ſalts, called *ſalt* of *gold*, *ſalt* of *copper*, &c. according to the various metals combined with the acid. The ſalt of ſilver is alſo called *luna cornea*; the ſalt of lead is often called *plumbum corneum*; and the ſalts of antimony, and of arſenic, are known by the names of *butter* of *antimony*, and *butter* of *arſenic*.

The acid of tartar (the pureſt part of which, or that ſaline ſubſtance which firſt cryſtallizes, by evaporation, in the veſſels in which it is purified, is called *cream of tartar)*, and alſo all other concrete vegetable acids analogous to it, when mixed with various other ſubſtances, form compounds, generally called *tartareous ſalts*, or ſoluble tartars, becauſe they are diſſolved by water more eaſily than the acid of tartar itſelf.

Acetous ſalts, that is all ſalts containing the acid of vinegar, are alſo combined with various baſes, and form ſaline ſubſtances of different names, the principal of which are the acetous ſalt of copper, called *cryſtals* of *venus*, or of *verdigriſe* by the Chymiſts, and *diſtilled* or *cryſtallized verdigriſe* in commerce; the acetous ſalt of lead, commonly called *ſalt*, or *ſugar of lead*; and the *acetous mercurial ſalts.*

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* *Ammoniacal ſalts* is alſo a general name given to all neutral ſalts compoſed of an acid ſaturated with a volatile alkali.

Sugar is an eſſential vegetable ſalt, of a pleaſant ſweet taſte, containing a vegetable acid combined with earth and oil.

Potaſh is a fixed vegetable alkali, extracted from the aſhes of wood. Concrete volatile alkalies are generally called *volatile ſalts*; although this name is ſometimes alſo given to the volatile ſalt of amber, which is not an alkaline, but an acid ſalt.

Borax is a neutral ſaline matter, whoſe origin, whether animal or vegetable, is as yet unknown, its components being not ſufficiently examined. It is ſoluble in water, and very nearly as cryſtallizable as alum. When borax is expoſed to the fire, it firſt bubbles and foams very much, but afterwards it melts into a clear glaſs. When acids are combined with the alkaline part of borax, a ſubſtance of a ſingular nature is ſeparated from it, commonly called ſedative ſalt. Although this ſubſtance acts as an acid in borax, by ſaturating its alkali, yet it has no acid taſte, nor doth it turn the tincture of heliotropium to a red, as other acids do. It is the property of borax to facilitate conſiderably the fuſion of metals, of earths, and other minerals. Some ſpecies of ſtones and earths cannot be vitrified at all, except they are mixed with borax. For this property borax is commonly uſed as a *flux* (that is, a ſubſtance which facilitates the fuſion of other bodies) in various manufactories; but eſpecially in ſoldering *metals*, and in aſſaying ores *.

Phoſphoric ſalts are combinations of alkaline, earthy, and metallic ſubſtances with the acid obtained from the *phoſphorus* of *urine*, which ſubſtance will be deſcribed hereafter.

Beſides the above-mentioned ſalts, there are ſeveral others to be met with in the writings of the chymical and medical authors; but as they are of little conſequence for our preſent purpoſe, we ſhall omit any account of them, and ſhall only mention a few intereſting particulars relating to the formation and properties of nitre; which ſalt furniſhes ample matter for ſpeculation in the ſubject of elaſtic fluids.

Nitre, as we have already mentioned, is a neutral ſalt, containing a particular acid called *nitrous acid*, and fixed vegetable alkali; for theſe ſubſtances may be obtained from nitre by decompoſition. It is found naturally cryſtallized in India only; but the quantity is very ſmall in compariſon to that uſed, which is furniſhed partly by nature, and partly by art. Beſides India, there is no place wherein this ſalt is found readily cryſtallized, or exiſting in great accumulated quantities like other minerals; but it is formed, as it ſeems, by the concurrence of various circumſtances; it being moſt commonly found in old walls of buildings, and in places impregnated with vegetable and animal juices *, ſuch as kitchens, ſtables, cellars, &c. eſpecially when they are low and moiſt †. This obſervation has induced ſeveral Chymiſts to believe, that nitre exiſts ready formed in vegetable and animal bodies, and that the fluids proceeding from thoſe bodies carry it off, and impregnate thoſe places in which it is found. The old Chymiſts ſuppoſed that nitre was formed by the concurrence of air and earth. They thought that a nitrous acid ſpirit exiſted in the air, which ſpirit, by gradually adhering to ſome earth, formed nitre ‡; but this opinion is at preſent rejected, becauſe ſeveral ſubſtances ſeemingly moſt proper to imbibe the nitrous acid, after being expoſed to the air for a conſiderable time, were not found to contain any nitre.

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* *Ores* are mineral bodies containing a metallic ſubſtance joined to other matters; generally earth, and ſulphur.

The nitre ſo found in places impregnated with animal or vegetable juices, is very impure, ſo that it cannot be uſed unleſs firſt purified by art. The method in general uſed by thoſe who make it their buſineſs to purify nitre, is the following:—

The pieces of earth and rubbiſh containing the impure nitre, being broken to ſmall fragments, are put into caſks, together with an equal quantity of wood-aſhes; then water

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* Some nitre may be obtained from ſeveral plants.

† The nitre brought from India is found upon the ſurface of the ground, eſpecially in thoſe places of India and Perſia upon which populous villages formerly ſtood; or which are contiguous to large rivers.

‡ See Mayow de ſal-nitro, et ſpiritu nitroaereo.

ter is repeatedly poured upon them, ſo as to waſh off all the ſaline matter from the rubbiſh. This water or *lixivium* is conſerved, and from it the nitre is to be obtained; in order to which, they put it in large copper cauldrons upon the fire, and leave it to evaporate. Now this lixivium contains two ſorts of ſalt, namely, common ſalt, and nitre; the firſt of which is cryſtallizable by evaporation, and the ſecond by cold; hence, when the lixivium has boiled and evaporated to a certain degree, the common ſalt cryſtallizes at the bottom of the cauldrons, and is taken away with proper ladles; then the remaining lixivium is removed from the fire, and carried into proper places to cryſtallize the nitre, which will be found formed into unſhapely maſſes; and is ſeparated from the water. This nitre ſo obtained is far from being pure, as it ſtill contains a quantity of common ſalt and other ſubſtances, from which it is ſeparated by diſſolving it in pure water, and ſuffering it to cryſtallize again. Thus the nitre is rendered more pure; and by repeating this operation, it is ſometimes purified a third and even a fourth time, in order to render it fit for the niceſt chymical operations.

Nitre is eaſily fuſed by a heat leſs than what is required to make it red hot, and if after fuſion it be left to cool, it coagulates into a ſolid ſemi-tranſparent body, called *mineral cryſtal*; which, however, beſides the form, retains all the properties of nitre before the fuſion.

The moſt remarkable property of nitre is, to aſſiſt the combuſtion of inflammable bodies. When it is properly mixed with various combuſtible matters, it contributes to their quick combuſtion ſo far, that they and the nitre explode with violence and noiſe, which is called *detonation*; hence nitre is a neceſſary ingredient in the compoſition of gunpowder, and becomes a very conſiderable article in commerce as well as in philoſophy. When nitre is decompoſed by ſtrong fire, it produces a permanently elaſtic fluid, not only analogous, but much purer than common air; it being capable to aſſiſt combuſtion and animal life much better and longer than air can. It is owing to this remarkable kind of elaſtic fluid, that the combuſtion of inflammable bodies is ſo much facilitated by their combination with nitre, that they may be made to burn even where air does not exiſt *. This elaſtic fluid, together with farther conſiderations on the nature of nitre, will be particularly examined in the following ſheets.

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* Compoſitions capable of burning under water, or in vacuo, are to be met with in the writings of various authors, eſpecially in OZANAM's Works.

CHAP. VI.

Of Earths.

THE bodies, which, beſides ſalts, make up the ſolid part of our globe, are divided by the beſt mineralogiſts into earths, inflammable minerals, metals, and ſemimetals. Moſt of the bodies belonging to thoſe claſſes are ſometimes found pretty pure, and ſeparate from other matter, in various places of the earth; but in general they are ſo intermixed together, that the greateſt endeavours of art are ſcarce ſufficient to aſcertain the particular components. Thus, for inſtance, various ſorts of earth contain a ſmall quantity of ſome metal or other, which is ſo intimately combined with it that it can with difficulty be obſerved; and probably a ſmall portion of every metal is to be found in earth of every kind.

The minerals comprehended under the claſs of earths, are bodies not ductile, generally not diſſoluble in water or oils, and which, when by themſelves, preſerve their conſtitution in a ſtrong fire. They may be arranged into the following orders, viz. 1. Calcareous earths. 2. Siliceous earths. 3. The Garnet kind. 4. Argillaceous earths. 5. The Micaceous kind. 6. The Aſbeſtus kind. 7. And the Zeolites.

The firſt order, under the denomination of calcareous earths, comprehends the lime-ſtone, chalk, the ſtalactites, otherwiſe ſtone icicles, or drop-ſtone, the various ſorts of marble, and others. The general properties by which the earths of this order are diſtinguiſhed from the others, according to CRONSTEDT's Mineralogy, are the following:

1. They become friable, when burnt in the fire, and afterwards fall into a white powder.

2. Their falling into powder is promoted, if, after being burnt, they are thrown into water; whereby a ſtrong heat ariſes, and a partial ſolution.

3. They cannot be melted, by themſelves, into a glaſs, in a ſtrong fire.

4. When burnt, they augment the cauſticity of the lixivium of potaſhes.

5. They are diſſolved in acids with efferveſcence.

6. They melt eaſily with borax, or ſal fuſibile microcoſmicum, into a glaſs, which ſuffers impreſſions in a degree of heat below ignition.

7. They melt the readieſt of all kinds of ſtones, with the calces, into a corroſive glaſs or ſlag.

8. They have alſo ſome power of reducing certain metallic earths or calces; for inſtance, thoſe of lead and of biſmuth, and likewiſe, though in a leſs degree, thoſe of copper and iron; which is a property of fixed alkaline ſalts; hence theſe earths are ſometimes called *alkaline earths*.

The ſecond, which might well be called the *precious order*, contains the hardeſt bodies among the earths, and indeed among all the known ſubſtances. The diamond, the ruby, the topaz, the opal, and other precious ſtones, the cornelian, the agate, the common flint, the jaſper, &c. are of this claſs; to all which Mr. CRONSTEDT aſſigns the following generic properties:

1. In their indurated ſtate they are hard, if not in regard to the whole, yet at leaſt in regard to each particle, in a degree ſufficient to ſtrike fire with ſteel, and to ſcratch it when rubbed againſt it, though the ſteel be ever ſo well tempered.

2. When pure, and free from heterogeneous particles, they do not melt by themſelves in a very ſtrong fire.

3. After being burnt, they do not fall to a powder, neither in the open air, nor in water, as the calcareous order does, but become only a little looſer, and more cracked by the fire, unleſs they have been very ſlowly and by degrees heated.

4. They excite no effervefcence with acids.

5. In the fire they melt eaſieſt of all to a glaſs with the fixt alkaline ſalts; and hence they have got the name of *vitreſcent*, though this name is, properly ſpeaking, leſs applicable to this order than to a great many other earths.

The minerals of the Garnet kind, as Mr. CRONSTEDT obſerves, might as well be arranged with thoſe of the Siliceous kind, becauſe they ſeem to be in every reſpect ſiliceous earths combined with a quantity of metal, generally iron; the different proportions of which render thoſe ſtones more or leſs fuſible, and conſtitute their different ſpecies.

The order of Argillaceous earths may be divided into two parts; one containing thoſe argillaceous earths, which are not diſſolvable by water; and the other containing thoſe, which grow ſoft in water, and when only moiſtened, become tenacious, ſo as to be ſhaped in any required form. Theſe are called *clays*; thus porcelain clay, common clay, &c. belong to this order of argillaceous earths; the common property of all which is, that they become hard in the fire, and when broken, exhibit a dull granulated ſurface, as if they were compoſed of very ſmall and diſtinct particles.

The earths called Micaceous have the following diſtinguiſhing properties:—They are compoſed of thin and flexible particles, which have a ſhining ſurface, and may be eaſily divided into leaves, which, if expoſed to the fire, loſe their flexibility, become brittle, and ſeparate into thinner leaves; but it is very difficult to fuſe them into a glaſs, without the addition of ſome other proper matter. Alkaline ſalts or borax facilitate their fuſion conſiderably.

The earths of the Aſbeſtus kind are diſtinguiſhable from the others by their being very refractory, that is, they are not altered in the fire, except that they are only rendered more brittle. They are partly flexible, and have a dull uneven ſurface. They are not acted upon by acids; but when mixed with borax, they are fuſible like other earths.

The Zeolites form a particular order, becauſe they are harder, than thoſe of the calcareous kind. They melt eaſily in the fire, occaſioning an ebullition like borax. In the fire they are more eaſily diſſolved by the fixed mineral alkali, than by any other flux. They are diſſolved by acids very ſlowly, and without any efferveſcence.

Beſides thoſe above-mentioned, there are ſome other earths of the magneſe kind, in French called *mangoneſe*, which, by ſome mineralogiſts, are conſidered like ores of metals; but we ſhall have occaſion to ſpeak of them in other places.

There are ſome calcareous earths to which ſome mineralogiſts give the name of *fluors* *, and arrange them into a particular order; owing to ſome ſlight difference which ſeemed to appear between theſe and the other calcareous earths. Mr. Scheele, a philoſopher of very great merit, by diſtilling a mixture of thoſe fluors and vitriolic acid, obtained an acid, which he conſiders as *ſui generis*, diſtinct from the vitriolic, the nitrous, or the marine acid. He gave it the name of *fluor acid*, admitting it as a fourth mineral acid. But Dr. Priestly, ſpeaking of this acid, in the 28th ſect. of his third volume of Experiments and Obſervations on different kinds of Air, conſiders it as nothing more than the vitriolic acid diſguiſed by the combination of the fluor earth. "In my former inveſtigations," ſays he, "of the nature of this acid, I advanced an opinion, ſufficiently ſupported, as I think, by experiments, that it is neither a new mineral acid, as Mr. SCHEELE, who made the firſt diſcoveries concerning it, ſuppoſed, nor the marine acid diſguiſed, as Mr. BOULANYER has conjectured; but in fact, nothing more than the *vitriolic acid itſelf*, that is employed in the ſolution of the ſpar, exhibited in the form of air, by means of the phlogiſton which it contains, and loaded with a quantity of *fluor cruſt*, which is part of the earth of the ſpar *."

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* The word *fluor*, in Chymiſtry, ſignifies alſo *fluid*: thus the acids, which are generally in a fluid form, are called *fluor acids*; whereas the eſſential acid ſalts, the acid of tartar, &c. are called concrete acids.

CHAP. VII.

Of Inflammable Minerals.

IN the preceding pages we mentioned, that a ſmall quantity of phlogiſton does probably exiſt in bodies of every kind. This quantity, when enveloped in a proportionably great quantity of earth or other matter, is inſufficient to render the compound inflammable; but when the quantity of the inflammable principle is ſo great, in compariſon to the other components, that the mineral body is capable of being inflamed, it is then called *inflammable mineral*; ſuch is ſulphur, pit-coal, &c. It has been the opinion of ſome philoſophers, that moſt of the bodies belonging to this claſs were originally generated from animal or vegetable ſubſtances, which, in a long period of time, meeting with acids and other ſubſtances in the bowels of the earth, underwent various changes, till they acquired the form in which they appear at preſent. The fact is, that the origin of moſt inflammable minerals is exceedingly doubtful. When chymically analyzed, they generally give a fetid empyreumatic oil, ſome earth, water, and a ſmall quantity of ſome ſalt or other. By a mixture of reſins, oils, and other vegetable or animal productions, ſome inflammable minerals are pretty well imitated; but we muſt not therefore conclude, that they were originated from the animal or vegetable kingdoms.

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* The name *ſpar* is given to thoſe cryſtallized ſtones, more or leſs tranſparent, which are found under ground, eſpecially in metallic mines, and are not hard enough to ſtrike fire with ſteel. By their properties they ſeem to belong to various orders of earths; hence they acquire various appellations, as *calcareous ſpars*, *gypſeous ſpars*, &c.

The bodies of this claſs, which are of a more general uſe, are ſulphur, amber, and ambergriſe, the rock-oil, the aſphaltum, and pit-coal.

Sulphur, among the ancient Chymiſts, and eſpecially Alchymiſts, denoted all kinds of inflammable ſubſtances, and with ſome, it ſignified only the inflammable principle;

hence they talked of the ſulphur of metals, the ſulphur of vegetables, the ſulphur of animal ſubſtances, &c.: but at preſent the word ſulphur has a more diſtinct and ſimple ſignification, denoting an inflammable mineral, commonly of a pale yellow colour, having a peculiar diſagreeable ſmell; and of great uſe in commerce as well as in philoſophy. It is a neceſſary ingredient in gunpowder, and various other compoſitions; and it is ſometimes alſo called *brimſtone.*

By analyſis this ſubſtance, when pure, is found to conſiſt of a large quantity of vitriolic acid, joined to the pureſt phlogiſton; and by a proper combination of thoſe two principles, ſulphur may be actually made. This mineral is found almoſt every where in the bowels of the earth, eſpecially in metallic mines; there being ſeldom any metal found without a greater or leſs quantity of ſulphur, which, on account of its volatility, is ſeparated from the metal by diſtillation or ſublimation. Sulphur uncombined with other matters, and almoſt pure, is often found in volcanoes, and grottos; and it is then called *native ſulphur.*

In the common temperature of the atmoſphere, ſulphur is brittle, ſo that it may be eaſily reduced into very fine powder. It is not diſſolved, nor in any ſenſible manner altered by water or air. Pure acids, and ſpirit of wine ſeem to have no action upon it. Sulphur cannot be diſſolved in oils, without heat ſufficient to melt it. Either fixed or volatile alkalies, and even calcareous earths, diſſolve ſulphur, and form with it compounds called *livers of ſulphur*; by which combination the ſulphur is rendered more or leſs ſoluble in water, according to the quantity and quality of the alkali with which it is combined. Acids of every kind, when added to liver of ſulphur, decompoſe it, and by joining themſelves with the alkali, detach the ſulphur from it. Liver of ſulphur, either liquid or concrete, has a diſagreeable, putrid, and offenſive ſmell; which ſhews that the attraction between the elements of ſulphur is much weakened by the combination of an alkali; indeed, the inflammable principle is continually eſcaping from it, and in ſuch abundance as to phlogiſticate various ſubſtances. Thus ſilver will be ſoon tarniſhed, and white lead will become of a browniſh black colour, when expoſed to the vapours of liver of ſulphur*. Chymiſts make great uſe of liver of ſulphur, on account of its being a powerful ſolvent, eſpecially of metallic matters.

Sulphur is eaſily fuſed by heat, in which caſe it emits very ſtrong ſuffocating vapours, which, if collected in proper veſſels, are called *flowers* of *ſulphur*, and prove to be in every reſpect the ſame ſulphur from which they were emitted, only more pure, becauſe the heterogeneous matters combined with it, remain moſtly at the bottom of the veſſel. When ſulphur is expoſed to fire in cloſe veſſels, it ſuffers no decompoſition; but in the open air, after being melted, it is eaſily inflamed by the contact of burning ſubſtances, or by an increaſed degree of heat. When it is made to burn ſlowly, its flame, which is generally of a blueiſh colour, is ſo weak that it is not capable of inflaming various combuſtible ſubſtances. For this reaſon, if gunpowder be expoſed to a proper gentle degree of heat, the ſulphur contained in it may be all burned away, without cauſing the powder to explode. Combuſtion ſeparates the two component principles of ſulphur; the phlogiſton being communicated to the air, and the vitriolic acid exhaling in vapours, which may be collected by impregnating the ſteam of water with them; and thus vitriolic acid is commonly obtained for the uſe of the ſhops. Sulphur unites eaſily with all metallic matters, excepting gold, platina, and zinc, with which it cannot be made to combine by any method yet known, without the intermediation of ſome other ſubſtance. The compounds of ſulphur and any metal, are not ductile, but poſſeſs a metallic luſtre. In this manner the metals are generally found in mines; that is, combined with ſulphur, and generally with various other matters beſides.

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* Upon this principle a very diverting experiment may be made, viz. Some words may be written with white lead and water upon a white piece of paper, which will not be legible; but if this paper is expoſed to the vapours of liver of ſulphur; for inſtance, is ſet upon a glaſs veſſel, containing a ſmall quantity of liver of ſulphur; the letters will become legible in a few hours, by acquiring a blackiſh colour, and appear as if they had been written by a kind of magic power.

It is a remarkable property of ſulphur, to facilitate the fuſion of very refractory metals, ſuch as iron and copper; and, on the contrary, to render the ſoft and moſt fuſible metals, as tin and lead, leſs fuſible.

Amber, ambergriſe, the aſphaltum, pit-coal, and the rock-oil, in Latin called *petroleum*, are generally called *bitumens*; the latter of which is the only liquid bitumen; it being an oil, which diſtils naturally from clefts in certain rocks; the reſt being all ſolid. When theſe ſolid bitumens are diſtilled, they are all found to contain ſome phlegm, an acid liquor often ſulphureous, ſome oil, much reſembling petroleum, a volatile acid and concrete ſalt, a black and thick oil, and at laſt a charry reſiduum, containing ſome earthy matter combined with part of the above-mentioned ſubſtances.

Amber is a ſemi-tranſparent mineral of a yellow colour, for which reaſon it is ſometimes called yellow amber, in diſtinction from ambergriſe. This mineral burns very eaſily, emitting thick fumes, and a ſmell, which is not diſagreeable. This ſmell may be perceived alſo by rubbing the amber, but it is not ſo ſtrong as when burning, or as that of the tincture of amber, obtained by means of rectified ſpirit of wine. Amber, as well as other bitumens, that are ſufficiently compact to bear a poliſh, are generally ſhaped into toys and ornaments of various ſorts. Some of them are alſo uſed for the preparation of varniſhes[*], eſpecially amber; which will make a fine black varniſh when diſſolved in boiling linſeed oil, after being rendered quite black in a crucible over the fire. Mr. NEUMAN, analyzing ſixteen ounces of coarſe amber, by means of diſtillation, obtained eleven ounces ſix drams of oil, four drams and a half of ſalt, one ounce and a half of water, and nearly one ounce of earthy or coaly reſiduum.

Ambergriſe is a ſubſtance of a grey colour, brought from the Eaſt Indies, where it is found floating upon the ſurface of the ſea. It is neither ſo hard nor ſo ſmooth as amber, ſo that it is not capable of receiving a poliſh. It is eaſily fuſed, and it may be rendered very ſoft, even by the heat of one's hands. The ſmell of this ſubſtance is very agreeable, for which reaſon it is uſed for perfumes. The components of ambergriſe ſeem to be the ſame as thoſe of amber, except that the former leaves a much leſs reſiduum than the latter.

The Rock-oil is an inflammable mineral, of a light brown colour when liquid, but black when indurated by being expoſed to the air, or found naturally ſo. This ſubſtance, as it is ſaid, cannot be decompounded by analyſis.

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[*] *Varniſhes* are liquids made by diſſolving bituminous or reſinous ſubſtances in ſpirits or oils; hence they are of two ſorts, viz. Spirit varniſh, and oil varniſh. Their uſe is to defend pictures and other things, over which they are laid, from the injuries of moiſt, air, and other things.

The Aſphaltum is a ſpecies of concrete rock-oil, which leaves no reſiduum when burnt. It is ſuppoſed by ſome, that the aſphaltum is the ſubſtance, which the ancient Egyptians uſed in embalming their dead bodies, which have endured ſo many centuries without corruption, and are now called *mummies.*

Pit-coal, or foſſil-coal, is a bituminous ſubſtance of a black or dark brown colour, found in large maſſes under the earth, in various countries, in which it is uſed for fuel. It commonly appears to be compoſed of plates, which are eaſily ſeparated from one another, eſpecially when the coal is heated. By analyſis, this mineral is found to contain the ſame principles that bitumens generally have, as mentioned above, except that it leaves a greater quantity of earthy reſiduum, which is of different ſorts, according to the different ſpecies of the coal; of which ſpecies there are reckoned three, viz. one that leaves a black reſiduum after combuſtion; another whoſe reſiduum is ſpongy; and a third ſpecies which leaves ſome whitiſh aſhes.

CHAP. VIII.

Of Metals.

METALS, or, in general, metallic ſubſtances, are bodies much more heavy, than earthy and other matters. They are quite opaque, and are generally capable of receiving a very high poliſh, owing to their compactneſs and opacity. They are generally diſtinguiſhed into *metals*, whoſe characteriſtic property is to be malleable; and *ſemi-metals*, which, when hammered, break into unſhapely fragments.

The metals are again ſubdivided into *perfect* and *imperfect*. The perfect metals are Gold, Platina, and Silver; which are called perfect, becauſe they cannot be decompounded; gold, for inſtance, if pure, will not loſe any of its eſſential properties by being kept in a very ſtrong fire. But the imperfect metals, which are copper, iron, tin, and lead, if they are kept a ſufficient time in the fire, or expoſed to the action of proper menſtruums, beſides fire, will loſe their metalline properties, and appear in the form of earths; which are vitrifiable, not ſhining, not malleable, &c. and are called *metallic calxes*; which may be again reduced into metals, or, as it is commonly ſaid, may be *revivified*, by combining them with a ſufficient quantity of inflammable principle: hence it appears, that the imperfect metals are principally, if not wholly, compoſed of earthy matter and phlogiſton. It is not every kind of earth which, combined with a ſufficient quantity of phlogiſton, can form a metal; nor can the calx of one metal, by any known method, be made to form another metal. The calx of iron, for inſtance, can form nothing but iron; the calx of lead will make only lead; and ſo of the reſt *.

Theſe obſervations relating to calcination, and revivification (called alſo reduction, or reſuſcitation) of calxes, are alſo applicable to the ſemi-metals.

The conſtant obſervation, that all the metallic ſubſtances which can at all be decompounded, are found to be compoſed of a metallic earth and phlogiſton, has induced the generality of philoſophers to think, that the perfect metals are alſo compoſed of like materials, ſo well combined, that the utmoſt efforts of art are not capable to part them. This, however, is nothing more than a conjecture, reaſonably deduced from analogy; for no ſuch thing could ever be produced as the calxes of any of the perfect metals, except when they are mixed in a ſmall quantity with certain ſubſtances, as glaſs and other things; in which caſe

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* The tranſmutation of one metal into another, or the making a metal out of ſomething elſe beſides a metallic earth, may, perhaps, be poſſible in nature; but it has been attempted by ſo many people, whoſe trials have proved unſucceſsful, after the expence of fortunes, and inconceivable labour; that whoever at preſent attempts any ſuch thing, is laughed at, being conſidered as a madman.

the appearance of their particular colour, and other conſiderations, ſeem to indicate at leaſt a partly calcination.

The metallic calxes are ſometimes partly or ſuperficially calcined, in which ſtate they are not ſufficiently deprived of their phlogiſton; ſo that they loſe the general properties of metals; yet if they are expoſed to a ſtrong fire, eſpecially that produced by a large burning-glaſs, they are revivified without the addition of any phlogiſton. In this caſe, either the phlogiſton of part of the calxes ſerves to ſaturate the reſt, or the ſmall quantity that they have got, is diſperſed through all their ſubſtance, ſo as to give them a ſufficient metallic appearance *. Thus, a metallic calx is, by ſome Chymiſts, miraculouſly revivified without the addition of phlogiſton.

The pure metals are always found in their metallic form; but the imperfect ones are generally found in the form of calxes; which, in order to be revivified, muſt be mixed with ſome ſubſtance containing phlogiſton, and muſt be expoſed to a ſtrong fire, by which means the metallic calxes will acquire the neceſſary quantity of phlogiſton from the combuſtible matters, and become metals. In this operation, the calxes and combuſtible ſubſtances are ſet in proper earthen veſſels, called *crucibles*, together with ſome alkaline ſalts, which ſerve to facilitate the fuſion; and they are alſo covered with ſand, which prevents the acceſs of air; otherwiſe the phlogiſton of the combuſtible ſubſtances would be imbibed by the air, inſtead of revivifying the calxes.

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* A ſmall quantity of phlogiſton may alſo be furniſhed by the air, if the operation is performed in that element.

It muſt be obſerved, that when ſome metallic earths, eſpecially that of tin, are too much calcined, they become incapable of reduction.

When a metal is calcined, the calx will be found heavier than the metal; and on the contrary, when metallic calxes are revivified, there is a loſs of weight; that is, the metal formed will weigh leſs than the calx.

All the metallic ſubſtances that are capable of decompoſition, are combuſtible; and in order to let them actually burn, it is only required to give them a ſufficient quantity of heat, when they are ſo diſpoſed as to preſent to the air a ſurface conſiderably large in compariſon of the quantity of matter. In this caſe they exhibit the ſame phenomena as other combuſtible bodies do, viz. they phlogiſticate the air, loſe their inflammable principle, &c.; but they do not produce any fumes or ſoot, like oils, which are compounds of phlogiſton, acid, water, and earth; but burn with a clear light, like charcoal, ſulphur, and all thoſe ſubſtances in which the phlogiſton exiſts pure; that is, diſincumbered of thoſe matters which can be eaſily volatilized. Steel filings, ſmall ſteel wire, fine powder of copper, &c. burn by the leaſt approach of ignited bodies. The ſparks commonly produced by ſtriking a flint againſt ſteel, are nothing elſe than particles of ſteel ſeparated by the hard flint, and ſet on fire by the violence of the ſtroke.

In general, acids and alkalies, as was obſerved above, and in ſome caſes alſo oils, water, and air, act upon metallic ſubſtances. Metals cannot unite with earthy matters; but they generally mix with one another very eaſily, forming compound metals, called *allays*; but the mixture of metals and quickſilver (which, as will be obſerved hereafter, is alſo a metal) are called *Amalgams*.

Gold is a perfect metal, of a ſplendid yellow colour, unalterable by art, and void of any taſte or ſmell, even when heated or rubbed. It is the heavieſt of all known bodies; although platina, when very pure, and freed from the iron with which it is generally combined, comes ſo near to the ſpecific gravity of gold, that it has been obſerved even to equal it. Pure gold is about nineteen times heavier than water; a cubic inch of it weighing ten ounces, ſeven pennyweights, three hundred and eighty-three grains, troy weight; whereas the ſame bulk of diſtilled water weighs very little above ten pennyweights. The expanſibility of gold is very ſurpriſing; a grain of it being commonly extended by the gold-beaters into leaves, whoſe ſurface is equal to fifty ſquare inches. Its tenacity, or the power with which it reſiſts the ſeparation of its parts, is greater than that of any other metal; a gold wire, one tenth of an inch in diameter, being capable to ſupport a weight of five hundred pounds without breaking. In reſpect to hardneſs, gold ſeems to be in an intermediate degree between the hardeſt and ſofteſt metals; yet by hammering, preſſing, or allaying it with a ſmall portion of ſome other metals, it may be rendered ſo hard and elaſtic, that even blades of knives and ſciſſors have been made of it. The malleability of gold is in great meaſure diminiſhed by cooling it ſuddenly after fuſion. It is alſo much diminiſhed by being expoſed to the exhalations of melted lead, tin, and moſt other metallic ſubſtances.

If gold is reduced into exceedingly fine powder, it is eaſily attacked by ſimple acid menſtruums; but while it is in a compact maſs, there is no ſimple ſolvent of it; hence gold remains for ages unaltered by air, water, &c. By the action of aqua regia, gold is reduced into exceedingly ſmall particles, but its metallic nature is in no reſpect altered *. The ſame thing happens when gold is mixed with quickſilver, and alſo with liver of ſulphur, which is alſo a ſolvent of gold.

If gold, after being diſſolved in aqua regia, be precipitated by a volatile alkali, and afterwards be waſhed and dried,

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* The ſolution of gold in aqua regia is corroſive, like the ſolution of any other metal; hence they are generally poiſonous; and ſhould be handled always with attention; for ſometimes they act very ſlowly, ſo that their pernicious effects are often perceived too late to be remedied.

dried, it acquires a wonderful property, which is peculiar to this metal only. It is that of exploding with a noiſe, quickneſs, and violence, which far exceeds the power of any other known exploding compoſition. It is therefore very dangerous, even for perſons much verſed in chymical operations. Gold ſo prepared is called *fulminating gold*; and in order to make it explode, nothing more is required than a ſmall degree of heat, even that produced by a gentle friction. It is ſuppoſed, that in the fulmination of gold, the metal is not at all altered or decompoſed; becauſe, when a ſmall quantity of it is exploded under a ſtrong glaſs receiver, ſmall particles of gold are afterwards found adhering to the ſides of the glaſs. But it may be ſaid, that the gold ſo found is not that, which has exploded, but only part of the quantity employed, which is diſperſed by the violence of that part of it, which has really exploded, by being firſt rendered the hotteſt. It is therefore ſtill uncertain, whether the gold is, or is not, decompoſed by the fulmination.

Thin eſſential oils, eſpecially ether, have a great affinity with gold; ſo that if ether be poured upon a ſolution of gold in aqua regia, and the mixture be ſhook, the gold will leave the latter, and paſs into the former.

Gold is eaſily melted in a low white heat, in which ſtate it appears of a bright blueiſh colour; but it does not emit any perceivable effluvia; it does not loſe any weight; nor is it at all altered, even if the fire is continued for months *.

Gold may be mixed with all metals; which, according to their different qualities, alter its colour, malleability, &c. The allay of other metals with gold renders it impure, and of courſe lowers its price. The purity and value of allayed gold is therefore eſtimated from the quantity of pure gold exiſting in the mixture; for inſtance, when the allay contains half gold and half ſilver, or other metal, the quality of the maſs is ſaid to be half ſo good as pure gold. Now theſe proportions of gold and other metals contained in the allay are commonly expreſſed by twenty-fourth parts of the maſs, which parts are called *carats*; thus when the compoſition contains twenty twenty-fourths of gold, it is called gold of twenty carats; when it contains half gold and half another metal, as in the above-mentioned example, it is called gold of twelve carats; and pure gold, without any allay, is called gold of twenty-four carats.

Platina is alſo a perfect metal, lately diſcovered in South America, in which place only it is to be found in the gold mines. Its ſpecific gravity is ſcarce leſs than that of gold;

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* Dr. LEWIS has obſerved, that although gold does not expand ſo much as other metallic bodies, in the ſame degree of heat, yet when fuſed, it expands more than moſt metallic ſubſtances; in conſequence of which, it ſhrinks conſiderably when it becomes ſolid after fuſion. Silver, copper, lead, and tin do not ſhrink ſo much; but iron, and a ſemi-metal called biſmuth, have the remarkable property of expanding, when from a fluid they paſs into a ſolid ſtate.

but its colour is white, though not ſo beautiful as the colour of ſilver. For theſe, and other properties of this metal, analogous to the properties of gold, it has obtained the name of white gold among various people. This metal is found conſiſting of angular grains, and in that form is brought to Europe: which grains are generally mixed with a little mercury, arſenic, and ſome ſmall black ſand, which ſeems to be iron, becauſe it is attractable by a magnet; but it is not diſſolved by acids, nor capable of fuſion. The hardneſs of platina is near that of iron, but it is ductile in a ſmall degree. Platina, like the other perfect metals, gold and ſilver, is void of ſmell and taſte, and is incapable of acquiring any ruſt. But it has the remarkable and peculiar property of being not fuſible nor alterable by the action of the ſtrongeſt fire yet tried, except the focus of a large burning-glaſs; which, by melting it, adds brilliancy to its colour, and increaſes its malleability. Platina, although exceedingly refractory by itſelf, when in company with other metals, with which it eaſily combines, or when previouſly diſſolved in aqua regia, may be fuſed pretty eaſily: hence all that platina which is ſeen manufactured, is allayed with ſome other metallic ſubſtance. This metal, like gold, is not attacked by any ſimple acid; but it is diſſolved by aqua regia: a large quantity of it, aſſiſted by heat, is required to diſſolve a comparatively ſmall quantity of platina; forming a ſolution of a deep yellow colour, even deeper than the ſolution of gold. The platina ſo diſſolved may be precipitated by alkalies; but this precipitate has not the property of exploding, like fulminating gold. Beſides alkalies, almoſt all metallic ſubſtances are capable to precipitate platina from aqua regia *.

Silver is the third perfect, conſequently unalterable metal, of a brilliant white colour, ſomewhat ſonorous, and fuſible in a leſs degree of heat than gold requires. The ſpecific gravity, as well as the tenacity of this metal, is nearly half that of gold ; a ſilver wire of one tenth of an inch in diameter being juſt capable to ſupport a weight of two hundred and ſeventy pounds without breaking. The weight of ſilver is to the weight of water nearly as eleven to one. The ductility of ſilver is greater than that of any other metal, but leſs than the ductility of gold.

This metal is found in various parts of the earth, commonly mixed with other metals, and with ſulphur or arſenic; from which ſubſtances it may be ſeparated by various means.

Silver is not acted upon by air or water; but it aſſumes a dark, and even a black colour, when it is expoſed to phlogiſtic exhalations; which is owing to the property which ſilver has of impregnating itſelf with the inflammable principle ſuperabundantly. Acids of every ſort are capable of diſſolving ſilver, but none ſo eaſily as the ni-

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* For other particulars relating to platina, ſee Dr. Lewis's Experiments on that metal.

trous acid ; yet it is remarkable, that either of the two other mineral acids is capable of ſeparating it from the nitrous acid : thus, if to a liquid containing marine or vitriolic acid in any quantity, a little of the ſolution of ſilver in nitrous acid be added, the mixture will immediately become turbid ; hence the ſolution of ſilver is very uſeful, to diſcover the preſence of marine or nitrous acid in any compound. The ſolution of ſilver in nitrous acid is more corroſive than the acid itſelf*. The *lapis infernalis*, which is a very powerful cauſtic, uſed in ſurgery, is nothing more than the ſaline concretion formed by the cryſtallization of this ſolution.

Copper is an imperfect metal, which, in point of ductility, comes next to the perfect metals. It is ſonorous, and harder than ſilver. The tenacity of its parts is ſuch, that a copper wire, one tenth of an inch in diameter, can ſupport a weight of about two hundred and ninety-nine pounds, without breaking. Its weight is to the weight of water as eight to one. Copper is eaſily affected by the combined action of air and water ; hence it is eaſily tarniſhed, and even calcined, by being expoſed to moiſt air. This calx, or ruſt, is of a green colour, and is commonly called verdigriſe.

Acids and alkalies of every ſort, and indeed almoſt all ſaline ſubſtances, beſides oils and other matters, are more or leſs capable of diſſolving copper ; forming ſolutions generally of a blueiſh or green colour. The ſolution of copper in vitriolic and vegetable acids, in oil, or water, is green; in marine acid, at firſt appears of a brown or yellow colour, but becomes gradually green; in nitrous acid, the ſolution is of a blueiſh colour inclining to green. The ſolutions of copper in acids become blue by the addition of alkali *. The ſolution of copper in volatile alkali has the remarkable property of appearing blue when expoſed to the air, and of becoming colourleſs when the communication between it and the common air is intercepted: thus, if a bottle containing this ſolution be left open, the colour of the liquor will be blue, but if the bottle be well corked, the colour will gradually diſappear; and if the bottle be uncorked, the ſurface of the liquor firſt, and gradually the whole of it, will acquire a beautiful blue colour; and in this manner the colour of this ſolution may be made to appear and diſappear as often as it is required.

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* This property is common to moſt metallic ſolutions.

Sulphur has a greater affinity to copper than to any other metal, except iron. It facilitates its fuſion, and combines very eaſily with it. In this ſtate of combination with ſulphur, and alſo with other metallic ſubſtances, copper is moſt commonly found in mines. In conſequence

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* A ſmall quantity of volatile alkali added to water, containing too ſmall a quantity of copper to be diſcovered by any other means, will immediately manifeſt the preſence of that metal, by giving a blue colour to the water; hence it is very uſeful in the analyſis of mineral waters.

of this great affinity, copper may be ſeparated from almoſt any metal by means of ſulphur.

This imperfect metal requires a ſtrong white heat before it melts; and by the combined action of fire and air, it may be eaſily burnt, deſtroyed, and calcined; in which caſe it emits very pernicious fumes; and when burning it ſmokes, and communicates to the flame a green or blue colour. Hence it may be eaſily ſeparated from the perfect metals; for if the compound, conſiſting of any perfect metal and copper, be expoſed to a ſtrong heat with the acceſs of air, the perfect metal will remain unaltered, whilſt the copper is calcined, and is either abſorbed by the earthen veſſel in which the operation is performed, or ſwims on the ſurface of the perfect metal.

Copper is eaſily allayed with all metallic ſubſtances; forming compounds, which differ in various particulars, eſpecially in point of hardneſs and colour. The moſt uſed of theſe allays are thoſe called *braſs*, which is a compound of copper and zinc, or *lapis calaminaris*, which is the ore of that ſemi-metal; *bronze*, or *bell-metal*, which is a compoſition of copper and tin; and *white copper*, which is an allay of copper, zinc, and arſenic.

We may laſtly obſerve, with reſpect to copper, that it has a very diſagreeable aſtringent taſte, and that it is very dangerous to be applied to the human body, eſpecially internally.

Iron, the moſt uſeſul metal, to which the arts owe their exiſtence, and the want of which could not be ſupplied by any other known metallic ſubſtance, is the hardeſt of all metals, the moſt elaſtic, and, after platina, the moſt difficult to be fuſed. At the ſame time, if tin be excepted, it is the lighteſt of all metals; its ſpecific gravity, compared to water, being as ſeven to one nearly. The tenacity of its parts is ſuch, that an iron wire, one tenth of an inch in diameter, can ſuſtain a weight of four hundred and fifty pounds; which is little leſs than the tenacity of gold.

Iron is the only ſubſtance attracted by the magnet, and which is itſelf capable of becoming a magnet; indeed, the magnets found within the earth, are nothing more than ores or minerals, the greateſt part of whoſe compoſition is iron in a metallic ſtate. By this property, the preſence of iron in any compound may be diſcovered by a magnet: but here two caſes muſt be conſidered; firſt, when the iron, mixed with any other ſubſtance, is in a metallic ſtate, in which ſtate only it is attractable by the magnet; hence, if the compound be powdered, and a magnet be applied to it, the particles of iron are eaſily ſeparated. Secondly, when the iron exiſts in the form of calx, that is, deprived of its phlogiſton, in which ſtate it is not at all attractable by the magnet; in this caſe, the mineral to be examined muſt be firſt put into the fire (which is called *roaſting* the mineral) for ſome time, in order to reſuſcitate the calx of iron; after which operation it is powdered, and a magnet is applied to it, which will ſeparate the particles of iron. This metal is eaſily deprived of its phlogiſton, and is reduced into ruſt or calx, called *crocus martis*, or *ſaffron of mars*; which is of a reddiſh colour much like brick-duſt. The combined action of water and air, or even water alone, will eaſily ruſt it. This fact is ſo well known, that in order to keep iron free from ruſt, it is accurately dried, and often is covered with ſomething capable to prevent any moiſture coming into contact with it, ſuch as oil, wax, &c. Acids of every ſort, eſpecially the nitrous, and alkalies, can diſſolve iron, exhibiting particular appearances; but they generally deprive it, at leaſt in part, of its phlogiſton, and in the act of diſſolving it, generate ſome elaſtic fluids: which will be particularly noticed hereafter.

When iron is expoſed to a fire not ſufficient to fuſe it, its ſurface is gradually calcined, and ſcales, partly metallic, are gradually ſeparated from it, which ſometimes burn with a very vivid light. Theſe ſcales, by a longer continuance of fire, may be perfectly calcined. Iron is ſufficiently malleable when cold, but by making it red hot, its malleability is increaſed very much. If iron, together with ſubſtances that abound with phlogiſton, be expoſed to a ſtrong fire without the free acceſs of air, it acquires an additional quantity of phlogiſton, and is then called *ſteel*, that is, a more perfect ſort of iron [*]; and by this combination it becomes harder, and of a more uniform and compact grain. Steel has a very remarkable and uſeful property, which is, that if it be made red hot, and ſuddenly cooled in water, it becomes ſo hard and brittle, that a file has no power upon it, and if ſtruck againſt a hard ſubſtance, it breaks rather than bends. This hardening of ſteel is called tempering [†]; and it is practiſed in almoſt all the manufactures of this metal, eſpecially in making edged tools. Iron, and eſpecially ſteel, when expoſed to fire, before it becomes red hot, acquires upon its ſurface only various colours ſucceſſively; the moſt predominant of which are, a reddiſh or browniſh yellow, and a beautiful ſtrong blue. By this means various ſteel ornaments are made blue, viz. by expoſing them to an equable heat till they acquire the blue colour, and then removing them before they become red hot, which is the next ſtep to it.

Sulphur has a very great affinity with iron, ſo that they eaſily combine together, and even act upon one another without the intermediation of fire *. The fuſion of iron is ſo much facilitated by ſulphur, that if a piece of iron in a white heat be rubbed over with a piece of ſulphur, it immediately falls into liquid drops; but in this caſe the iron and the ſulphur are combined together, ſo that the iron loſes its malleability, and they form a kind of artificial mineral, or pyritous ſubſtance.

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[*] Iron being very difficultly fuſed, requires a long operation before its calx is ſufficiently impregnated with phlogiſton; hence iron commonly contains a good deal of unmetallized earth in its compoſition; the different proportions of which earth conſtitute the various ſorts of iron.

[†] Different degrees of hardneſs may be communicated to ſteel, by making it more or leſs hot, and plunging it in water, oil, or other liquor, which cools it more or leſs ſuddenly; for the hotter the ſteel is made, and the quicker it is cooled, the harder it becomes; and contrarywiſe.

Iron may be allayed with every metal, except lead and mercury; for hitherto no method has been diſcovered of combining it with thoſe bodies.

Iron, either in a calcined or in the metallic ſtate, is not only harmleſs, but it is uſed as a medicine; becauſe it poſſeſſes the property of ſtrengthening the fibres and veſſels, eſpecially thoſe of the ſtomach and inteſtines. For theſe uſes iron or ſteel is variouſly prepared, and the operations are generally very eaſy, except that of making an impalpable powder of ſteel, called *martial ethiops*, without calcining it; which proceſs, as till lately practiſed, was very long and laborious; but a very ſhort method of making ſuch a powder was diſcovered a few years ago; which is as follows:

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* Take ſulphur, and iron or ſteel filings, of each about ſixty pounds, and with a ſufficient quantity of water make it into a paſte, which may be ſet a few inches under ground. In ſome hours time this compoſition will ſwell, become hot, emit vapours, and at laſt will take fire; evidently ſhewing the action of ſulphur and iron upon each other independent of extraneous heat. This experiment is deſcribed in various books, and they generally give it the name of *artificial earthquake.*

Some fine clean ſteel filings are put in a ſhallow earthen pan over a very gentle fire (the heat of a lamp is quite ſufficient). Theſe filings are to be moiſtened with nitrous acid very much diluted with water, and muſt be kept ſtirring continually. They will bubble very gently, ſhewing as if they were in a fermentation. As they dry, more diluted nitrous acid muſt be added, ſtill ſtirring them, in order to mix them well with the acid, and to give them an equal degree of heat. This operation being continued for about an hour and half, the filings will be found upon trial to be reduced into a very fine powder. Some part of this powder is certainly calcined; but five parts out of ſix, or more of it, are attractable by the magnet; which ſhews that the greateſt part of it is iron in a metallic ſtate.

Tin is the lighteſt, and, if lead be excepted, it is the ſofteſt, the leaſt elaſtic, and leaſt ſonorous of all metals. Its colour is white, but not ſo beautiful as the colour of ſilver. Its ductility, although leſs than that of gold or ſilver, is, however, very conſiderable; it being eaſily worked into very thin foil. The tenacity of its parts is ſuch, that a tin wire, one tenth of an inch in diameter, is juſt capable to ſupport a weight of forty-nine pounds and a half.

All acids are more or leſs capable of diſſolving tin; generally depriving it of its phlogiſton, eſpecially the nitrous acid. The combined action of water and air has no other effect upon this metal, beſides that of ſlightly tarniſhing its ſurface. Sulphur may be combined with tin by means of fuſion, with which it forms a brittle body, not ſo eaſily fuſible as tin by itſelf is.

A degree of heat leſs than that required to make tin red hot, is ſufficient to melt it, and if continued, to reduce it into an imperfect grey calx, called aſhes of tin *, which, by continuing the action of a ſtronger fire, are more and more accurately calcined, becoming much whiter, harder, and very refractory; for which reaſon it is combined with ſome vitrifiable matter, and is uſed as a white glazing to cover earthen ware. This calx, in ſuch a ſtate, is called *putty*, and is advantageouſly uſed for poliſhing metals, glaſs, and other hard ſubſtances. In the calcination of tin, a ſmell is perceived, exactly like the ſmell of arſenic, a moſt dangerous ſemi-metal; which ſmell is owing to ſome quantity of arſenic commonly mixed with tin; hence this metal is conſidered as dangerous for phyſical, and even for culinary purpoſes.

Tin may be allayed with all metals, but it deſtroys their ductility, eſpecially of gold and ſilver; even the vapour of tin, when in fuſion, is capable of impairing the ductility of the metals expoſed to it. The amalgama of tin and quickſilver is uſed to cover the ſurfaces of looking-glaſſes; a compoſition of lead and tin, in equal quantities, forms the ſolder commonly uſed by plumbers; and an allay of tin and copper forms bell-metal, by which combination the copper acquires hardneſs, and ſonorouſneſs; which is the more remarkable, becauſe tin is a very ſoft and unelaſtic metal.

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* Tin and lead combined together, are more eaſily calcined by the action of fire, than either of them by itſelf.

Lead is a metal of white colour, but rather darker than tin. It is the ſofteſt, leaſt ductile, leaſt ſonorous, and the tenacity of its parts is leſs than that of any other metal; a leaden wire, one tenth of an inch in diameter, being juſt capable of ſupporting ſomething more than twenty-nine pounds. The ſpecific gravity of lead is very conſiderable, and, indeed, if gold, platina, and mercury, be excepted, it is the heavieſt of all metals.

Acids of every ſort are, more or leſs, capable of diſſolving lead. By expoſing lead to the fumes of vinegar, a fine white ruſt is formed upon the ſurface of this metal, which is called *ceruſs*, or *white lead*, and is much uſed in painting in oil.

The combined action of air and water does alſo corrode lead, but not ſo much as copper and iron; although the ſurface of lead is ſooner tarniſhed, even by air only.

Moſt oils have a conſiderable action upon lead, and eſpecially upon its calxes, with which they may be copiouſly combined, by the help of a moderate heat. By this combination the oils are not only thickened, but acquire the property of drying much eaſier; hence linſeed-oil, thus thickened, is called drying oil by the painters, who make great uſe of it. In this manner ſome oils may be rendered

dered ſo thick, that ſeveral plaſters uſed in ſurgery are made only by combining certain oils with a ſufficient quantity of calx of lead.

Sulphur not only combines with lead very eaſily, forming a compound which much reſembles the ore of lead; but facilitates its calcination, when expoſed to fire with the free acceſs of air.

This metal melts very eaſily with a degree of heat much leſs than is required to make it red hot. After being melted, it is ſoon calcined, and its calxes are more eaſily vitrified and revivified than the calxes of other metals *. The calxes of lead, when firſt formed by the action of a moderate heat, are of a greyiſh colour; but by the continuance of the ſame low degree of heat, they gradually become of a yellow colour, in which ſtate they are called *maſſicot*, or *yellow lead*; and then they acquire a red colour, in which ſtate they are called *minium*, or *red lead*. With a greater degree of heat, viz. ſufficient to fuſe thoſe calxes, they are reduced into a vitrified ſubſtance, called *litharge*. But if the heat is greater than that required to keep them barely in fuſion, then they are reduced into a true glaſs, called *glaſs of lead*, which has the ſingular property of penetrating through the pores of the earthen crucibles, juſt like water through a ſieve. This glaſs of lead does alſo facilitate the calcination of all the imperfect metals, eſpecially of iron; hence lead is much uſed to purify the perfect metals, when they are allayed with other metallic ſubſtances, as they are commonly extracted from mines; for by mixing the allayed perfect metal with a proper quantity of lead, and expoſing them to a ſtrong fire, with the acceſs of air, the lead combines with the imperfect metals, facilitates their calcination, the vitrification of their calxes, and even carries them with itſelf into the ſubſtance of the veſſels containing them, whilſt the perfect metal remains pure and unaltered. This method of purifying the perfect metals is called *cupellation.*

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* It is a general obſervation, that the calx of any metal, the more it is deprived of the inflammable principle, (viz. the more accurately it is calcined) the more difficult it is to be reduced; hence the calxes of lead, by being eaſily revivified, ſhew, that in every ſtate, they always retain a conſiderable quantity of phlogiſton.

Lead, like all other imperfect metals, has a particular taſte and ſmell. Its calxes, when taken internally, are poiſonous; but in various diſeaſes, their external application has been attended with very good ſucceſs.

Mercury, or quickſilver, is a ſingular ſubſtance, of a ſhining white colour, like ſilver, perfectly opaque, and the heavieſt of all known bodies, excepting gold and platina. Theſe, and other properties to be mentioned preſently, ſhew that quickſilver is a real metal; but then it has a peculiar property, by which it differs from all other metallic ſubſtances; this is the property of generally appearing in a fluid form. Formerly, the fluidity of quickſilver

ſilver was thought to be as eſſential to its nature as it is to air; but in the year 1759, Mr. Braun, of Peterſburg, availing himſelf of the great cold of that winter, ſtill increaſed by artificial means, viz. by pouring nitrous acid upon ſnow, did actually congeal quickſilver, exhibiting it in a ſolid form, of the ſame ſhining white colour as when fluid; in which ſtate it was extended by the ſtrokes of an hammer, and whilſt it continued in that congealed ſtate it ſounded when ſtruck, and was cut juſt like lead. This capital diſcovery completely demonſtrates the metallic nature of this ſubſtance, and obliges us to conclude that quickſilver is a metal fuſible by a very low degree of heat, namely, the uſual heat of the atmoſphere.

Air and water, neither ſeparate nor together, have any action upon quickſilver. Its ſurface indeed appears tarniſhed after being expoſed to the open air for ſome time; but that appearance, on examination, is found to be occaſioned only by duſt and watery particles, the latter of which quickſilver ſeems to attract from the air conſiderably. Pure quickſilver does not loſe any ſenſible weight by being kept in boiling water for a conſiderable time; yet the practice of many very able phyſicians, who have preſcribed ſuch water for various diſorders, ſeems to ſhew, that the quickſilver communicates ſomething to the water; perhaps the quantity is ſo ſmall, that hitherto it has not been perceived by our weighing inſtruments.

A degree of heat, leſs or equal to that of boiling water, ſeems not to have any effect upon this metal, but a greater degree of heat does entirely diſſipate it into elaſtic vapours, which, if collected, will be found to be, in every reſpect, the ſame quickſilver from which they aroſe. For this property quickſilver is very eaſily diſtilled, by which means it is ſeparated from lead, tin, and other metals, with which it is often combined *. If ſulphur be mixed with quickſilver, then quicklime, or iron filings, muſt be added to it, and afterwards muſt be diſtilled in order to purify it. Beſides diſtillation, there is another method of purifying impure quickſilver, deſcribed by Dr. PRIESTLY, which conſiſts in ſeparating from it all the blackiſh powder that is produced by agitating quickſilver for a ſufficient time. "I take a glaſs phial," ſays the Doctor, "with a ground ſtopper (ſuch being generally "pretty ſtrong) containing ten or twelve ounces of wa-"ter, and fill about one fourth of it with the foul quick-"ſilver; then, putting in the ſtopper, I hold it inverted "with both my hands, and ſhake it violently, generally "ſtriking the hand that ſupports it againſt my thigh. "When I have given it twenty or thirty ſtrokes in this

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* Mercury may be ſeparated from duſt, and alſo in a great meaſure from water, by ſtraining it through ſhamois leather, or by letting it paſs ſeveral times through a paper funnel, that is, a piece of paper rolled in a conical ſhape, having a very ſmall hole at the bottom. It may be ſeparated from greaſe, by waſhing it in an alkaline lixivium; and from an alkaline mixture by vinegar.

“ manner, I take out the ſtopper, and blow into the phial
“ with a pair of bellows; which I do in order to change
“ the air, that has become in part phlogiſticated, and
“ knowing, that the purer the air is, the faſter the pro-
“ ceſs advances.

“ After a ſhort time, if the mercury be very foul, the
“ ſurface will not only become black, but a great quan-
“ tity of the upper part of it will be, as it were, coagu-
“ lated, ſo as to be eaſily ſeparated from the reſt. I
“ therefore invert the phial, and covering the mouth of
“ it with my finger, let out all the mercury that will
“ flow eaſily, and put the black coagulated part into a
“ cup by itſelf. This I preſs repeatedly with the end of
“ my finger, till I make a complete ſeparation of the
“ running mercury from the black powder; and putting
“ the powder by itſelf, I pour back the mercury to the
“ reſt of the maſs out of which it was taken, in order to
“ be agitated with it again.

“ This proceſs I repeat till I find that no more black
“ matter can be ſeparated; and it is not a little remark-
“ able, that the operator will be at no loſs to know when
“ the proceſs is completed. For the ſame quantity of
“ lead ſeems to come out of it in equal times of agitation,
“ and conſequently the whole becomes pure at once.
“ Alſo, whereas, while the lead was in the mercury, it
“ felt, as I may ſay, like ſoft clay, the moment the lead

"is ſeparated from it, it begins to rattle as it is ſhaken, "ſo that any perſon in the room may perceive when it "has been agitated enough*.

The purity of quickſilver may, in general, be known by its not ſoiling the paper funnel through which it is made to paſs, by leaving no pellicle upon its ſurface, and, as Dr. PRIESTLY remarks, by obſerving, that when pure quickſilver is contained in a glaſs or earthen veſſel, its ſurface is convex, and a hollow ſpace is between the metal and the veſſel; whereas, if the quickſilver contains lead or tin, the whole ſurface of it, even to the place of contact with the veſſel, will be perfectly level; which Dr. PRIESTLY thinks to be owing to the attraction of the parts of the quickſilver, by which it always endeavours to acquire a ſpherical ſhape, being leſſened by the mixture of thoſe other metals. It is obvious to remark, that this obſervation cannot take place, except when a conſiderable quantity of other metals is mixed with the mercury.

If about two or three ounces of quickſilver be put into a glaſs veſſel, whoſe capacity might contain twice or three times that quantity of quickſilver, and having a narrow and long neck, terminating in a capillary aperture; and if this veſſel be expoſed to an equable but ſtrong fire for ſeveral months, the mercury will be gradually converted into a red powder, which floats upon the ſurface of the yet liquid mercury, or adheres to the ſides of the veſſel *. In this manner the mercury may be all converted into that red powder, which is improperly called *precipitate per ſe*, or *red precipitated mercury without addition*. This precipitate per ſe may be again reduced to fluid quickſilver, by heat only, without the addition of phlogiſtic matter; for which reaſon many imagine that the quickſilver, by being turned into precipitate per ſe, is not calcined, as many others have thought, but is only diſguiſed by acquiring or loſing that ſuperabundant quantity of phlogiſton unneceſſary to its metalline exiſtence, which this and other facts ſeem to ſhew, that can eaſily adhere to, or be ſeparated from mercury. At laſt, it muſt be confeſſed, that our preſent knowledge of this ſingular phenomenon is very imperfect, and requires the aſſiſtance of farther experiments.

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* Experiments and Obſervations on Air, &c. Vol. iv. Sect. 16.

All acids and alkalies are, more or leſs, capable of combining with mercury. Vitriolic acid acts upon quickſilver only when it is very much concentrated, and aſſiſted by a conſiderable degree of heat, reducing it into a ſaline white matter, which will become again the apparently unaltered quickſilver when the acid is ſeparated from it. This ſaline white matter, when diluted in water, forms a white powder if the water is cold, and a yellow powder if the water is hot; which powders are accordingly called *white precipitate*, and *yellow precipitate*, of *mercury*. The ſolution of mercury in vitriolic acid being diſtilled, and hot water being at various times thrown upon the reſiduum, a ſhining yellow citron-coloured powder is obtained, which is known by the name of *turbith mineral*, and has a ſtrong emetic power.

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* The heat neceſſary for this proceſs muſt be very little leſs than that required to make the glaſs veſſel red hot, otherwiſe the mercury will not be altered. The famous BOERHAAVE, after ſubjecting quickſilver to a moderate fire for fifteen years, found no other alteration in it, than a little black powder upon its ſurface, which was again reduced into quickſilver by trituration.

The nitrous acid diſſolves mercury more eaſily than any other acid, ſo that it hardly requires the aſſiſtance of any heat. From the ſolution of mercury in this acid a ſalt is obtained, called *mercurial nitre*, which, by being expoſed to the action of fire, will gradually change its white colour into yellow, then orange, and laſtly red; in which ſtate it reſembles the precipitate per ſe, and is improperly called *red precipitate*; which acquires the name of *arcanum corallinum*, after that ſpirit of wine has been poured and burned upon it.

If vitriolic acid, or any neutral ſalt containing this acid, be added to a ſolution of mercury in nitrous acid, the liquor will become turbid, and when heated, a yellow precipitate will be depoſited, which is exactly like turbith mineral. Hence the ſolution of mercury in nitrous acid is of great uſe in the analyſis of mineral waters, when they are ſuſpected to contain vitriolic acid.

Marine acid does not act upon quickſilver, except only when its vapours meet with the vapours of that metal.

In this caſe they unite very eaſily, forming a ſalt, compoſed of cryſtals reſembling flattened needles, and known by the name of *corroſive ſublimate*, on account of its great corroſive quality. This ſalt has the peculiar property of being very difficultly diſſoluble in water, whereas all other ſalts poſſeſs juſt the contrary property. It is alſo remarkable, that if corroſive ſublimate be expoſed to fire, it ſublimes again, that is, it riſes in vapours, which being collected in proper veſſels appear to be the ſame unaltered ſubſtance. If corroſive ſublimate be combined with as much more quickſilver as it will take by trituration *, and the compound be ſublimed three times; then the acid will be ſo well combined with the mercury, and in ſuch a quantity, that the ſublimate loſes its cauſticity, or corroſive quality, inſtead of which it becomes mild, and, in the practice of phyſic, is uſed as a purgative; it is therefore called *ſweet mercury*, *ſweet ſublimate* of *mercury*, or *calomel*. By ſubliming ſweet mercury five or ſix times more, it gradually loſes its purgative quality, and in that ſtate is called *mercurial paracea*. If marine acid, or any ſalt containing that acid, be added to a ſolution of mercury in nitrous acid, the mercury and the marine acid will combine together, and form a white precipitate, which is different from turbith mineral, in being diſſoluble in water, whereas turbith mineral is not. Theſe obſervations ſhew, that although the nitrous acid diſſolves mercury, as in general it does other metallic ſubſtances, more eaſily than any other acid, yet mercury has a greater affinity with the vitriolic or marine acid, than with the nitrous; for we have remarked, that mercury is ſeparated from the nitrous by either of the other two acids.

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* When the corroſive ſublimate is triturated in a mortar with quickſilver, which muſt be added by little and little, the quickſilver will diſappear by incorporating with the ſublimate; and when no more quickſilver can be ſo combined, will be known by the globules of fluid mercury, which remain unabſorbed in the mortar, although the trituration be carried on.

Vegetable acids in general have hardly any action upon quickſilver, except this metal be very much divided, as when it has been previouſly diſſolved, and precipitated. Thus a ſufficient quantity of vinegar being added to mercury, precipitated from its ſolution in nitrous acid by a fixed alkali, the vinegar will diſſolve again, and combine very intimately with the mercury.

An entertaining phenomenon may be obſerved, by agitating quickſilver in vinegar. "A very little agitation," ſays Dr. PRIESTLY, "of mercury in this acid "divides it into the ſmalleſt globules; and they continue "without any apparent diſpoſition to re-unite, even when "very hot. While this divided mercury is in the vinegar, "the globules may be poured from one part of the phial "to the other exactly like fine dry ſand, and they ex-"hibit a ſingular and beautiful appearance. All the "vinegar muſt be evaporated by heat before theſe globules "will unite *."

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* Experiments and Obſervations on Air, &c. Vol. iv. Sect. 17.

Alkalies, either fixed or volatile, when added to the ſolution of mercury in acids, precipitate the metal; and the precipitates acquire various colours, which variety is particularly owing to the different degrees of diviſion ſuffered by the mercury; but if the alkaline liquor poured upon the ſolution of mercury, made in a more than neceſſary quantity of acid, is very concentrate, then the precipitate which is formed on firſt mixing the ſubſtances, will be ſoon diſſolved again, and will diſappear; which ſhews, that alkalies have power to diſſolve mercury when its parts are much divided; whereas they have no ſenſible power of acting upon it whilſt it exiſts in its uſual metalline ſtate.—This property of certain ſubſtances acting upon other ſubſtances only in particular circumſtances, as my reader muſt have often remarked in the preceding pages, is very often obſervable in chymiſtry, and to expreſs with preciſion the various affinities of bodies, in the form of tables, is thereby rendered very difficult and equivocal.

Mercury may be ſeparated from its combination with acids, by alkalies, or other ſubſtances that have a greater degree of affinity with thoſe acids. Thus if an alkali be added to the ſolution of mercury in an acid, and the mixture be diſtilled, the mercury will be obtained in its fluid metallic form. But in this operation it muſt be conſidered, that when the ſubſtance mixed with the combination of mercury and an acid, is of a volatile nature, then the mercury will be diſtilled along with part of that ſubſtance, and will form a new combination, from which it muſt be ſeparated by different means, which vary according to the nature of the ſubſtance combined with the mercury.

If ſulphur and quickſilver be triturated together, or the quickſilver be mixed with melted ſulphur; theſe two bodies will incorporate with each other, and form a blackiſh ſubſtance, called *ethiops mineral* in the firſt caſe, and *ethiops made by fire* in the ſecond. If this ethiops be ſublimed, that is, be reduced into vapours by fire, and theſe vapours be collected in proper veſſels, and be again ſublimed for ſeveral times; the combination of the mercury and ſulphur will be gradually rendered more and more intimate, and at laſt becomes a very heavy maſs of a deep red colour, called *cinnabar*; which being powdered, is uſed in painting, and is called vermilion by the painters. In this operation, part of the ſulphur of the ethiops ſeems to be ſeparated from it by the ſucceſſive ſublimations; and by a proper analyſis, cinnabar is found to contain only one part of ſulphur joined to ſix parts of mercury.

Cinnabar is alſo found native in the mines, and it is juſtly conſidered as the ore of mercury. In order to obtain the mercury from this ore, the cinnabar is mixed with fixt ſubſtances, that have a greater affinity to ſulphur than mercury has (iron filings are the beſt and more generally

uſed),

uſed), and then the mixture is diſtilled, by which means the ſulphur will combine with the other ſubſtances mixed with the cinnabar, and the mercury will be diſtilled over in its fluid metallic form. The mercury thus revivified, or rather ſeparated, from the cinnabar, is conſidered as the pureſt, and conſequently fit for the niceſt philoſophical purpoſes.

Quickſilver, like other metals, cannot be combined with earthy matters, but it may be allayed more or leſs eaſily with all metallic ſubſtances, except iron, arſenic, the regulus of antimony, cobalt, and nickel. Theſe allays, or, as they are more commonly called, *amalgams*, are more or leſs ſoft according to the various proportions of mercury, and according to the nature of the other metal mixed with it. By diſtilling theſe amalgams it is found, that the mercury carries along with itſelf ſome portion even of the heavieſt and moſt perfect metal with which it is combined. This ſhews, that mere diſtillation is not ſufficient to ſeparate the mercury from other metals.

All oily and fat matters, either vegetable or animal, can combine with mercury by trituration, forming dark-coloured ſubſtances, called *mercurial ointments*.

If quickſilver be agitated for a conſiderable time in any veſſel, part of it will be reduced into a black powder, which, by means of heat, can be reduced again into fluid quickſilver. This powder has been conſidered as mercury partly calcined, that is, deprived of its phlogiſton; but ſome late experiments and obſervations of Dr. PRIESTLY, who has agitated quickſilver, not only in air, but alſo in water and other fluids, ſeem to ſhow, that the above-mentioned black powder is rather mercury overcharged with phlogiſton; which ſuperabundant quantity of phlogiſton the mercury may poſſibly receive from the ſubſtances in which it is agitated *.

If mercury in its natural metallic ſtate is taken internally, it does not produce any remarkable effect, becauſe the ſtrong attraction between its parts prevents its penetrating the ſmall veſſels of the human body; but when its parts are much divided, by its combination with other matters, or otherwiſe, it then acts as a moſt powerful remedy for ſeveral diſorders, and is therefore very much uſed in the practice of phyſic; but as moſt of the preparations of this metal are of dangerous nature, they ſhould be always managed with great attention, and by ſkilled phyſicians; for they are not only dangerous when exceſſively uſed, but alſo when they meet with ſuch ſuperabundant fluids in the human body, which can alter their nature; and thus, from their being inoffenſive, they may become abſolutely poiſonous.

Having thus deſcribed the principal properties of metals in as ſhort a manner as the importance of the ſubject would permit, I ſhall conclude this long chapter with a few general remarks relating to metals. The old Chy-

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* Experiments and Obſervations on Air, &c. Vol. iv. Sect. 16. 17.

miſts, who, inſtead of rendering their art plain and familiar, endeavoured to conceal it under myſterious and perplexing expreſſions, gave various extravagant names to almoſt all the objects of their examination, and eſpecially to the metals, which it was their intereſt to examine more often, and with greater attention. The preſent more illuminated age has juſtly rejected the greateſt part of thoſe appellations; but yet ſome of them are ſtill in uſe with ſeveral modern authors, which renders it neceſſary to mention them, in order that the peruſal of various excellent books might not perplex the novices in this intereſting branch of philoſophy.

Gold has been often called *Sol*, the *Sun*, and the *King* of metals. Silver has been called alſo *Luna*, the *Moon*; hence the names *luna cornea*, and *lunar cryſtals*, are derived. Copper obtained the name of *Venus*, which gave the appellation of *cryſtals* of *Venus* to the cryſtallized ſaline combination of vinegar and copper. Iron was alſo called *Mars*; hence we often hear of *martial earth*, *martial ethiops*, *ſaffron of Mars*, &c. Lead was called alſo *Saturn*: and quickſilver, as we have already mentioned, obtained the appellation of *Mercury*, which name is now more frequently uſed than that of quickſilver.

In the various combinations of metals and acids mentioned above, it has been often remarked, that ſuch metal may be ſeparated from its ſolution in a menſtruum by this or that other ſubſtance; but in various caſes this remark has been neglected, becauſe it ſeemed a needleſs ſuperfluity, after that the various affinities of acids and alkalies had been clearly mentioned in the preceding liſts. We may, therefore, obſerve in general, that when a metal, or other ſubſtance, is combined with an acid, or an alkali, the ſubſtances may be parted by all other bodies called *intermediate*, viz. that have a greater degree of affinity with that acid or alkali, than the ſubſtance actually combined with it. Thus, for inſtance, if ſilver be diſſolved in nitrous acid, it may be ſeparated from that acid by alkalies, by lime, by copper, and other ſubſtances, which are ſet before ſilver in the liſt of affinities given in page the 28th.

The calcination of metals, as it is a very ſingular phenomenon in Chymiſtry, ſo it is far from being ſufficiently underſtood. The methods of calcining the imperfect metals may be reduced to three, viz. by the action of fire, by acids in certain circumſtances, and by detonating them with nitre *. The ſecond of theſe methods is called the *humid way*, becauſe it is done by means of liquors, or at leaſt without the aid of fire; and on the contrary, the firſt is called the *dry way*. In any way, the calcination of metals is attended with ſome general appearances, which are of a very remarkable nature. Firſt, according as the calxes are more accurately deprived of phlogiſton, they

* There may be added, that ſome metals are calcinable by being amalgamed with mercury, as it has been remarked above.

become more difficultly reducible, more refractory, leſs volatile, and leſs ſoluble in acids, eſpecially in the nitrous; which properties ſeem to ſhew that their fuſibility, volatility, &c. are in great meaſure, if not entirely owing to the preſence of phlogiſton. Secondly, the calx of a metal is found to be abſolutely heavier than the metal before calcination. Thus, if an ounce of lead be calcined, the calx will be found to weigh ſomething more than an ounce; and the metal obtained from one ounce of calx of lead will weigh leſs than one ounce. This increaſe of weight has been attributed to two various cauſes; for ſome perſons, ſuppoſing that phlogiſton gives levity to bodies, thought that the calx of a metal became heavier in conſequence of its loſing the phlogiſton; but the more reaſonable opinion is, that the ſaid increaſe of weight is owing to the adheſion of elaſtic fluids, which combine with the metallic calxes in the very act of calcination, and which is ſeparated from them as ſoon as they are reduced to a metallic ſtate. Laſtly, it may be juſt hinted, for the conſideration of my contemplative readers, that various metallic calxes are in great meaſure diſſoluble in water, which property ſhews that they have ſomewhat of a ſaline nature; perhaps the elaſtic fluids, or that matter, whatever it is, which generates the elaſtic fluids obtained from thoſe calxes, renders them ſo.

CHAP. IX.

Of Semi-metals.

THE Semi-metals are thoſe ſubſtances which have all the general properties of metals, excepting fixity and malleability *; for they can be ſublimed by a ſufficient degree of heat, and may be powdered, rather than extended, by the repeated ſtrokes of an hammer. Theſe bodies are Zinc or Spelter, Regulus of Antimony, Biſmuth, and Regulus of Cobalt; to which may be added, Nickel, Manganeſe, and another ſemi-metal, which Mr. JUSTI pretends to have diſcovered; but theſe, eſpecially the laſt, are very imperfectly known.

Arſenic is a ſubſtance which has all the properties of a ſemi-metal, at the ſame time that it poſſeſſes a ſaline property; it may therefore be conſidered as belonging to both claſſes of bodies.

Zinc or Spelter is a ſubſtance which comes very near to the nature of a metal, or which rather ſeems to be in an intermediate ſtate between metals and ſemi-metals; it being partly ductile, eſpecially when it is well furniſhed with the inflammable principle. This ſubſtance is of a brilliant white colour inclining to blue, and of a conſiderable ſpecific gravity; it being ſomewhat more than ſeven times the weight of an equal bulk of water. The great quantity of phlogiſton exiſting in zinc, which is ſlightly engaged in its compoſition, renders it the moſt combuſtible of all metallic ſubſtances; hence it detonates with nitre more violently; producing a more vivid flame than any other combuſtible body; for which reaſon it is often uſed in compoſitions for fire-works.

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* Mercury being very volatile, and generally fluid, which implies not malleable, has been, by ſome perſons, conſidered as a ſemi-metal; but it muſt be conſidered, that mercury is incombuſtible, and when congealed has been found to be malleable, which properties are incompatible with the nature of ſemi-metals.

Zinc, when heated, is very brittle. If expoſed to a ſufficient fire, it melts when it is become almoſt red hot, and in this ſtate its ſurface is converted into a grey calx, which, by addition of phlogiſton, after the uſual manner of reducing metallic calxes, may be eaſily converted again into zinc. In a white heat this ſemi-metal burns with a dazzling white flame, exceedingly luminous and brilliant. In this combuſtion the earthy part of zinc, which is conſiderably fixed, riſes in form of white ſmoke, and either floats in the air or adheres to the bodies it meets with, in the form of flocks, which are called *flowers of zinc*, or *philoſophic wool*. Theſe flowers, if collected, and expoſed again to a ſtrong fire, they rather melt than ſublime a ſecond time. By being expoſed to a ſtrong heat, together with inflammable bodies, in cloſe veſſels, they may be again converted into zinc.

This ſemi-metal, when broken, appears compoſed of many flat and ſhining plates, which are larger, when it has been ſlowly cooled after fuſion, than otherwiſe.

The combined action of water and air ſeems to have as little action upon this ſubſtance as it has upon tin. All acids are, more or leſs, capable of diſſolving zinc, and alſo its flowers; which ſeems to ſhew, that the latter are never intirely deprived of phlogiſton. The white vitriol, or vitriol of zinc, is made by diſſolving one part of zinc in ſix parts of vitriolic acid, diluted with an equal quantity of water.

Zinc may be combined more or leſs eaſily with all metallic ſubſtances, excepting biſmuth and nickel. It is remarkable, that when united with copper, even in a conſiderable proportion, it diminiſhes very little the malleability of that metal, and at the ſame time renders its colour more beautiful, and more like the colour of gold. This colour varies according to the different proportions of theſe two metallic ſubſtances in the compound, which acquires different names accordingly, as *braſs*, *tombac*, *ſimilor*, *pinchbeck*, and *prince's metal*. The zinc for theſe compoſitions muſt be very pure, and free from other metallic bodies. The method of purifying this ſemi-metal, which is principally founded upon its property of not uniting with ſulphur, is thus deſcribed by Mr. MACQUER:—When zinc is melted in a large crucible, ſuet and ſulphur alternately, and the latter in larger quantities than the former, muſt be thrown upon it. If the zinc is pure, the ſulphur burns freely on its ſurface; but if it is allayed, the ſulphur combines with the other metals, and forms with them a kind of ſcoria, which muſt be taken off. This alternate projection of ſuet and ſulphur upon zinc is continued till the ſulphur be burnt on the ſurface of the melted zinc without forming any ſcoria; the zinc thus purified, may be ſucceſsfully employed for making of braſs or metallic mixtures in imitation of gold.

Antimony is a ſubſtance commonly found in unſhapely maſſes, which appear compoſed of long brittle needles of a ſhining leaden colour. In this ſtate it is called *native*, or *mineral antimony*; which, when it is ſeparated from ſtones and other earthy bodies, by fuſion, is called *fuſed antimony*. This mineral is a compound of ſulphur and a ſemi-metallic ſubſtance, called the *regulus* of *antimony*, which may be ſeparated from the ſulphur by various proceſſes, the ſimpleſt, though the longeſt, of which is *torrefaction*, or, as it is commonly called, *calcination*. For this purpoſe the antimony, groſsly powdered, is expoſed to a moderate fire in a flat and ſhallow earthen veſſel, and is kept continually ſtirring. In this caſe the ſulphur of the antimony, which is more volatile than its regulus, eſcapes in vapours, and leaves the ſemi-metallic part of antimony by itſelf, which, however, is partly deprived of its phlogiſton, and is accordingly more fixed, and leſs fuſible, than crude antimony *. It is therefore called *calx* of *antimony*, and is of a grey aſh-colour. This calx, if expoſed to a ſufficiently ſtrong heat, melts, and when cold appears an opake brown ſubſtance, called *liver* of *antimony*; but a greater degree of heat, viz. a more perfect calcination, renders this calx a brittle tranſparent ſubſtance of a hyacynthine colour, called *glaſs* of *antimony*. All theſe three preparations of antimony, viz. the calx, the liver, and the glaſs, when taken internally, are violent emetics; whereas antimony is not. Either of theſe preparations, by the addition of combuſtible matters, after the common method of revivification, may be reduced into regulus of antimony; which is a hard, brittle, ſemi-metallic body, of a leaden white colour, appearing compoſed of ſmall ſhining ſurfaces.

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* This operation muſt be continued till no more ſulphurous vapours are emitted.

The regulus of antimony may be alſo ſeparated from the ſulphur by the intermediation of other metallic ſubſtances, which have a greater affinity with ſulphur than the regulus of antimony; ſuch are copper, tin, lead, ſilver, and, beſt of all, iron; any of which metals, when added to fuſed antimony, will combine with the ſulphur, and leave the reguline part by itſelf. The regulus of antimony thus obtained acquires the name of the metal employed for its ſeparation, viz. *martial regulus*, *regulus* of *copper*, *regulus* of *tin*, &c. Another method of obtaining the regulus of antimony is the following:—A mixture, conſiſting of eight parts of powdered antimony, ſix parts of tartar, and three parts of nitre, is thrown at different times into a crucible, which muſt be red hot, and ſurrounded with burning coals. This mixture will detonate, but after the detonation the fire muſt be increaſed ſo as to fuſe the matter remaining in the crucible; then the crucible is removed from the fire, and, when cold, is broken, in order to obtain the ſubſtance it contains, which will be found conſiſting of two diſtinct matters, namely, the regulus of antimony, and a cruſt lying over it, which is called the *ſcoria of the regulus of antimony*, and may be ſeparated from the former by a ſtroke of an hammer. This ſcoria is compoſed of part of the ſubſtances uſed in the proceſs, in ſome meaſure altered by their combination, and by the action of fire. It is of an alkaline acrid nature: it attracts the moiſture of the atmoſphere, and is decompoſed by it.

By detonating antimony with three times its weight of nitre, a white maſs is obtained, which is the calx of antimony joined to ſaline matters, the latter of which may be ſeparated by waſhing, and then the calx is called *diaphoretic mineral*, *diaphoretic antimony*, or *white calx* of *antimony*. This calx, which is conſidered as entirely deprived of phlogiſton, is very fixed, is inſoluble in acids, and may be reduced again into regulus of antimony by expoſing it to the action of a ſtrong fire, together with inflammable ſubſtances, in cloſe veſſels.

Whenever antimony is expoſed to a degree of heat capable of fuſing it, a volatile matter eſcapes from it, which is its reguline part, in ſome meaſure deprived of phlogiſton. This matter adheres to any cold body it meets with, and is called *flowers* of *antimony.*

Kermes mineral is a precipitate of antimony, very much uſed in medicine. The proceſs for making it is thus deſcribed by Mr. MACQUER:—" When crude antimony is " boiled in a lixivium of fixed alkali, a liver of ſulphur is " formed from the combination of this alkali with the " ſulphur of the antimony, by which the metalline part of " the antimony is diſſolved. But the alkali, by its being " diſſolved in water, having but a ſlight union with the " ſulphur, this antimoniated liver of ſulphur cannot be " kept ſuſpended in the water, when the heat of that " fluid is leſs, or much leſs, than is ſufficient to make it " boil. Hence, when the liquor cools, it becomes tur" bid ; and a brick-coloured ſediment falls down, which " has been called *kermes mineral.* This precipitate drags " down along with it, according to a general rule of all " precipitates, a portion of the alkali by which it was " kept diſſolved. But this portion of alkali is very ſmall. " For this reaſon alſo the kermes cannot be kept diſſolved " but in very hot water. Hence it appears, that kermes " is nothing but an antimonial liver of ſulphur, contain" ing the ſmalleſt poſſible quantity of alkali, or a ſu" perabundant quantity of ſulphur and regulus of anti" mony.

" Kermes may alſo be made by fuſion, that is, by melt

" ing in a crucible dry alkaline ſalt and crude antimony, " and then diſſolving the combination in boiling water. " The ſame phenomena appear, as in the preceding ope- " ration, and for the ſame reaſons."

The regulus of antimony is very difficultly diſſolved by acids; and the marine acid ſeems to have no action at all upon it; but aqua regia, eſpecially when compoſed of four parts of nitrous and one part of marine acid, diſſolves it completely.

Butter of antimony, ſo called from its butiraceous appearance, is a very corroſive metallic ſalt, obtained by diſtilling powdered antimony, or its regulus, mixed with corroſive ſublimate. This butter of antimony is very eaſily and violently diſſolved by nitrous acid.

Biſmuth, or *tin-glaſs*, is a ſemi-metal of a dull white colour, ſeemingly compoſed of cubes, formed by the adheſion of plates upon each other. The ſpecific gravity of biſmuth exceeds that of any other ſemi-metal, it being about nine times heavier than water. When this ſemi-metal is expoſed to the action of fire, it melts in a low degree of heat, namely, about the four hundred and ſixtieth degree of FARENHEIT's thermometer. In a degree of heat greater than that required to keep it barely in fuſion, flowers ariſe from it, like the flowers of zinc; it is calcined; and is reduced into a litharge, and laſtly, a glaſs.

When biſmuth is combined with ſulphur, with which it has a good degree of affinity, it forms a ſtriated mineral body, ſimilar to antimony. All metallic ſubſtances, excepting zinc, the regulus of cobalt, and arſenic, may be combined with biſmuth. In this combination it is obſervable, that this ſemi-metal increaſes the fuſibility of the other metallic bodies, eſpecially of tin and lead: hence it may be uſed inſtead of lead to purify gold and ſilver in the proceſs of cupellation: it is alſo uſed in compoſitions for ſolders, for foiling of glaſs mirrors, and other purpoſes. An allay of tin and biſmuth in equal quantities is fuſible in a degree of heat equal to the two hundred and eighty-third of FARENHEIT's thermometer; and an allay of one part of lead, four parts of tin, and five parts of biſmuth, melts in a degree of heat nearly equal to that of boiling water, which anſwers to two hundred and twelve degrees of the above-mentioned thermometer *.

The vitriolic acid has no power of properly diſſolving biſmuth. The marine acid diſſolves a ſmall quantity of it very ſlowly, and with difficulty. But the nitrous acid diſſolves it with heat and effervеſcence; the ſolution appearing of a pale red colour, and when cold, it concretes into ſmall cryſtals. By adding water to this ſolution, a beautiful white precipitate is obtained, called *magiſtery of biſmuth*; and when freed from adhering acid by waſhing, is uſed by painters, under the appellation of *Spaniſh white*. This precipitate, like white lead, imbibes phlogiſton very readily, whenever it meets with it, and in that caſe it becomes black.

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* See Dr. MARTINE's Eſſays, Medical and Philoſophical, p. 366.

Biſmuth, like all other calcinable metallic bodies, is eaſily calcined with nitre, but it does not detonate with it.

Cobalt is a name given to various heavy minerals, containing different matters, but among them always one, which may be reduced into a calx, called *zaffre*, and may be vitrified; in which ſtate it acquires a beautiful blue colour, and is the only ſubſtance uſed to give a blue tinge to glaſs and other vitrifications. This blue vitrified ſubſtance, by means of phlogiſtic bodies in a ſufficient fire, may be revivified into a brittle ſemi-metallic ſubſtance called *the regulus of cobalt.*

The calx as well as the regulus of cobalt has the ſingular property of making what is called ſympathetic ink; that is, a liquor with which one may write upon paper, and may make the writing appear and diſappear at pleaſure.

The eaſieſt and beſt method of making this ſort of ink is the following:—Keep ſome zaffre in nitrous acid, till this acid can diſſolve no more of it, then dilute the ſolution with water, and that is the ink required. With this liquor characters or drawings may be marked upon white paper, which will not appear when the paper is cold and rather moiſt, but when expoſed to a moderate degree of heat, viz. about equal to that of the ſun-light in ſummer, they immediately acquire a beautiful green colour, and conſequently become plainly viſible. Thus the ſame characters may be made to appear and diſappear as often as it is required, by the alternate application of heat and cold. When the paper thus marked is expoſed to the fire, care muſt be taken not to give it a more than ſufficient degree of heat, for then the characters will not diſappear again by cold, but remain always upon the paper.

Nickel is a ſemi-metal, found combined with cobalt, iron, and other minerals; but it has never yet been found by itſelf. It was firſt diſcovered by Mr. CRONSTEDT; who, in the acts of the Royal Academy of Sciences at Stockholm, for the years 1751, and 1754, deſcribes it in the following manner:

“ I. It is of a white colour, which however inclines
“ ſomewhat to red. II. It is of a ſolid texture, and ſhining
“ in its fractures. III. Its ſpecific gravity to water is as
“ eighty-five to ten. IV. It is pretty fixt in the fire;
“ but together with the ſulphur and arſenic, with which
“ its ore abounds, it is ſo far volatile, as to riſe in form
“ of hairs and branches, if in the calcination it is left
“ without being ſtirred. V. It calcines to a green calx.
“ VI. This calx is not very fuſible, but however tinges
“ glaſs of a tranſparent reddiſh brown, or jacinth colour.
“ VII. It diſſolves in aqua-fortis, aqua-regia, and the ſpirit
“ of ſea-ſalt, but more difficultly in the vitriolic acid,
“ tinging all theſe ſolutions of a deep green colour. Its

“ vitriol is of the ſame colour ; but the colcothar * of this
“ vitriol, as well as the precipitates from the ſolutions, become
“ by calcination of a light green colour. VIII.
“ Theſe precipitates are diſſolved by the ſpirit of ſal ammoniac,
“ and the ſolution has a blue colour ; but being
“ evaporated, and the ſediment reduced, there is no copper,
“ but a nickel regulus is produced. IX. It has a
“ ſtrong attraction to ſulphur ; ſo that when its calx is
“ mixed with it, and puts on a ſcorifying taſte under the
“ muffel, it forms with the ſulphur a regule : this regule
“ reſembles the yellow ſteel-grained copper ores, and is
“ hard and ſhining on its convex ſurface. X. It unites
“ with all the metals, except quickſilver and ſilver. When
“ the nickel regulus is melted with the latter, it only adheres
“ cloſe to it, both the metals lying near one another
“ on the ſame plane ; but they are eaſily ſeparated with
“ a hammer. Cobalt has the ſtrongeſt attraction to
“ nickel, after that of iron, and then to arſenic. The
“ two former cannot be ſeparated from one another but
“ by their ſcorification, which is eaſily done, ſince, XI.
“ This ſemi-metal retains its phlogiſton a long time in
“ the fire, and its calx is reduced by the help of a very
“ ſmall portion of inflammable matter : it requires, however,
“ a red heat before it can be brought into fuſion,

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* Colcothar is properly the ſubſtance remaining after the calcination and diſtillation of martial vitriol with a violent fire.

" and melts a little ſooner, or almoſt as ſoon as copper " or gold, conſequently ſooner than iron."

The Manganeſe, or minerals of the manganeſe kind, are ſome dark-coloured maſſes, conſiſting of various ſhining particles, from which bodies ſome earth, a little iron, and often a very ſmall quantity of tin may be obtained. Some mineralogiſts have conſidered theſe minerals as earths, whilſt others ranked them among the ores of iron; and ſome perſons even think, that they contain a ſemi-metal different from the other ſemi-metals hitherto deſcribed. It muſt be obſerved, that this mineral contains a prodigious quantity of elaſtic fluid in a condenſed ſtate, or of that ſubſtance, whatever it may be, which by various means may be made to acquire the form of an elaſtic fluid, in many reſpects ſimilar to air.

Arſenic is a heavy and brittle ſubſtance, whoſe colour nearly reſembles the colour of lead, but by expoſure to the air it ſoon changes its ſhining colour, firſt to yellow, and then to black. When broken, it appears laminated in the fractures. The *white arſenic* is the calx, or flowers of arſenic, which by the addition of phlogiſton, may be again reduced into arſenic, or, as it is more commonly called, into *regulus of arſenic.* This ſubſtance is commonly arranged amongſt the ſemi-metals; but it poſſeſſes many ſingular properties, which render it different from the other ſemi-metals, and indeed from any other claſs of bodies. It is always volatile, whether in the form of

regulus

regulus or of flowers, and in the fire burns with a ſmall flame, and produces a diſagreeable ſmell like garlick; by which ſmell its preſence in any compound may be eaſily known. White arſenic is diſſoluble in all acids, and in water, for which property it reſembles ſaline ſubſtances. When put upon the tongue, it gives an acrid and hot ſenſation; and however applied to the human body, it always acts as a moſt violent corroſive poiſon; nevertheleſs in ſome caſes a ſmall quantity of it has ſometimes been preſcribed as a remedy.

Arſenic eaſily unites with all metallic bodies, excepting mercury, with which it has no affinity; rendering them brittle, and changing, in great meaſure, their colour; hence it is uſed in various metallic compoſitions in imitation of ſilver *. It alſo renders more volatile, vitrifies, and ſcorifies all ſolid bodies, excepting gold, ſilver, and platina; and increaſes the fuſibility of various very refractory bodies.

Its great fuſibility is by no means diminiſhed by a more perfect calcination, which is juſt the reverſe of what happens with other metallic calxes: indeed, the great volatility of arſenic prevents its being expoſed to a very intenſe heat; however, when it adheres to ſome ſorts of earths, it can even ſuſtain a vitrifying heat; for it is often

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* Arſenic is an ingredient in the metallic compoſitions called *white copper*, and *white tombac*; and alſo in the compoſition of ſome metallic reflectors.

uſed in the compoſition of ſome ſorts of glaſs, to which it gives a great whiteneſs and clearneſs.

Arſenic decompoſes nitre very eaſily; for when thoſe two ſubſtances are diſtilled, the nitrous acid is ſeparated from its baſis, whilſt the arſenic combines with that alkaline baſis of nitre, and forms with it a neutral kind of ſalt, which Mr. MAQUER, who firſt examined it, calls *neutral arſenical ſalt*. This ſubſtance may be eaſily combined with ſulphur, forming a compound which, from its colour, is called *yellow arſenic*, when the proportion of ſulphur to arſenic in the mixture is as one to nine; and *red arſenic*, when that proportion is as one to four. By this combination with ſulphur, arſenic becomes a little leſs volatile, and more fuſible; ſo that red arſenic may be melted, in which caſe it becomes tranſparent, and is then called *ruby* of *ſulphur*, or *arſenical* ruby. Combinations of arſenic and ſulphur are alſo found natural, either by themſelves, or together with other bodies, eſpecially with cobalt. Theſe natural compounds of arſenic and ſulphur, when yellow, are called *orpiment*, *orpin*, and *yellow rizigal*; and when they are of a red colour, are called *ſandarach*, *realgar*, or *red rizigal.*

The arſenic may, in ſome meaſure, be ſeparated from ſulphur by ſublimation, on account that the latter is more volatile than the former; but a more perfect ſeparation of theſe two bodies muſt be made by means of ſome intermediate ſubſtances; the beſt for which purpoſe are fixed alkali and mercury.

In conſequence of the above-mentioned and other obſervations, it ſeems, that arſenic is principally formed by a particular acid, which, when it is united to a ſmall quantity of phlogiſton, forms white arſenic; and with a greater quantity of the inflammable principle forms the regulus of arſenic.

CHAP. X.

Of Vegetable and Animal Subſtances.

THE Vegetable kingdom, or the claſs of thoſe organized bodies which have the power of growing and propagating the ſpecies, but are deſtitute of ſelf-motion, comes next to the Mineral in point of ſimplicity; for among the minerals we obſerved ſeveral bodies ſo homogeneous in their ſubſtance, that no art could ever alter, or diſcover any variety of principles in them; but the vegetables are never ſo ſimple. Some earth, ſalt, water, and oil is to be found in every plant; and various particular plants contain a ſmall portion of ſome other ſubſtances beſides.

The great chymical difference between the Mineral and the other two kingdoms of nature is, that the vegetable and the animal bodies furniſh an inflammable fat or oily ſubſtance, which is not to be obtained from any mineral [*]. It is owing to this oil that animal and vegetable bodies are ſuſceptible of fermentation, whereas the mineral bodies are not. The particulars by which the principles of vegetables differ from thoſe of animal bodies are, that the ſaline principles of the former are generally acid, and by being reduced into aſhes, they are moſtly changed into fixed alkali; but the ſaline principles of the latter either are, or may be eaſily changed into volatile alkalies. The oils of animal bodies in general are alſo more attenuated, and more eaſily volatiliſed; for which reaſons animal ſubſtances are more ſubject to putrefaction than vegetables.

Some vegetable ſubſtances, eſpecially ſeeds, when ſtrongly compreſſed, yield a mild, fat, and unctuous oil, which in general is not diſſoluble in ſpirits [†]. It is called *expreſſed oil*, and often *fat oil*, from its unctuouſneſs. Such oils are ſuppoſed to exiſt, in the bodies from which they are extracted, in the ſame ſtate as we ſee them; whereas the oils that are extracted by means of diſtillation, are altered by the action of heat. Theſe oils have an acid taſte, and are ſoluble in ſpirit of wine.

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[*] This propoſition is founded upon the ſuppoſition, that bitumens, and other ſuch-like oily ſubſtances found in the bowels of the earth, derive their origin from vegetable or animal bodies, which is a very probable opinion.

[†] The rind of lemons, oranges, and ſome other vegetable matters, when only ſqueezed, yield an oil which is much thinner and lighter than the expreſſed oils. It retains the odour of the fruit, and is ſoluble in ſpirit of wine.

Plants in general, that are not very dry, when compreſſed, yield a juice, which contains a great deal of water, ſome ſalt, a ſmall quantity of oil, and a very little portion of earth. When this expreſſed liquor has been kept for ſome time in a cool place, it depoſits ſome ſaline cryſtals, called *eſſential ſalts*, which contain the acid of the plant combined with a proportionably ſmall quantity of oil. When the plants are very dry and ligneous, they muſt be ſteeped and triturated in water for a conſiderable time, in order to extract their eſſential ſalts. Sometimes theſe eſſential ſalts cannot be obtained, or not without difficulty, when they are enveloped in much oil: in which caſe part of the oil of the plant may be firſt extracted by means of ſpirit of wine; after which the ſalts may be more eaſily obtained. When the liquors containing the eſſential ſalts of plants are evaporated, the reſiduums, which become about as conſiſtent as honey, are called *extracts*. Some extracts are alſo made by only boiling the plants in water; but in general they are not eſteemed ſo good as the others.

The oil of plants extracted by triturating them in ſpirit of wine, is ſeparated by the addition of water; for the ſpirit of wine having a greater affinity to water, will combine with it, and will leave the oil by itſelf, which may then be ſeparated, by decanting the liquor attentively.

With the aid of fire, the analyſis of plants may be carried much farther than by the above-deſcribed means. The fat oils may be obtained by only boiling the plants in water. When a freſh vegetable ſubſtance is expoſed to a very gentle degree of heat in a diſtilling veſſel, it gives firſt a thin and very volatile liquor, which retains the ſmell of the plant, and has been called *ſpiritus rector.* If water is put into the diſtil together with the plant, and the fire be raiſed ſo as to keep the water boiling, then the eſſential oil of this plant, together with the water, will be diſtilled over. It has been found, that if the ſpiritus rector has been firſt drawn from a plant, no eſſential oil can afterwards be obtained from it. After having extracted the eſſential oil, if the plant be diſtilled without water, it will firſt yield a phlegm, which grows gradually acid; then by increaſing the fire, a thicker and heavier oil is obtained. Some plants do alſo yield ſome volatile alkali; and laſtly, a thick and fœtid oil is diſtilled, called *empyreumatic oil.* The fixed part of the plant, which remains in the diſtil, is a coaly reſiduum, called *caput mortuum* by the chymiſts; which reſiduum may be burned to aſhes in the open air, and from theſe aſhes a fixed alkali is obtained by waſhing them in water, and ſuffering the lixivium to evaporate.

The Animal kingdom, which, agreeably to our deſign, comes next to be examined, is by far more compounded than either the Mineral or the Vegetable. To deſcribe particularly the nature, elements, and properties of the various fluids and ſolids belonging to animal bodies in general, would require a very long detal, by far exceeding the limits of this introduction, and perhaps quite unneceſſary for the main object of this book. We ſhall therefore content ourſelves with a ſhort account of the components of animal ſubſtances, conſidered under general heads, and without minutely examining every particular.

The ſucculent, fleſhy parts of an animal juſt deprived of life, when only compreſſed, yield a liquor which contains moſt of the principles of the animal body. A juice much of the ſame nature is obtained by boiling the hard and dry parts of an animal, ſuch as horns, bones, cartilages, &c. Theſe juices by evaporation are reduced into thick jellies, or animal extracts, which differ from the vegetable extracts in their affording no cryſtals of eſſential ſalts, and do not ſhew any ſign of acid or alkaline principle. The animal oil, which is ſo far analogous to the fat oil of vegetables, as to be mild, unctuous, not diſſoluble in ſpirit of wine, and attenuated by the action of fire, exiſts moſtly in ſeparate pieces called *fat*, and may be ſeparated by a knife *.

There is very little acid obtainable from animal bodies; which however ſeems to be different from the mineral or vegetable acids. Some inſects, eſpecially ants and cantharides, furniſh particular acids, which are diſtinguiſhed by the names of thoſe inſects. The acid of ants, which has been pretty well examined, has affinity with the following ſubſtances.

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* Animal ſubſtances do not contain any light eſſential oil, like vegetables.

1. Pure ponderous earth,
2. Fixed vegetable alkali,
3. Fixed mineral alkali,
4. Pure lime,
5. Pure manganeſia,
6. Volatile alkali,
7. Zinc,
8. Magneſia,
9. Iron,
10. Lead,
11. Cobalt,
12. Copper,
13. Nickel,
14. Arſenic,
15. Biſmuth,
16. Antimony,
17. Silver,
18. Platina,
19. Pure argillaceous earth, &
20. Water.

From the urine, eſpecially of the human ſpecies, a ſalt is obtained, called *native*, or *eſſential ſalt of urine*, *phoſphoric ſalt*, and *microcoſmic ſalt*. It is a neutral ſalt, containing a particular acid called *phoſphoric acid*, becauſe, when properly combined with phlogiſton, it forms a ſubſtance called *phoſphorus*, from its property of ſhining in the dark *; and a fixed or volatile alkali. This ſalt is obtained by evaporating urine, till it becomes nearly as conſiſtent as honey, and then leaving it to cryſtalize in a cool place. When this ſalt is expoſed to the action of a ſtrong fire in cloſe veſſels, a very penetrating volatile alkali is diſengaged from it, but the acid remains at the bottom of the veſſel.

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* The method of preparing this phoſphorus from urine will be deſcribed in the ſequel.

The phoſphoric acid is ſo fixed, that it may be made red hot without evaporating. In this manner it may be reduced into a ſolid and tranſparent body like glaſs. This acid has affinity with the following ſubſtances.

1. Pure lime,
2. Pure ponderous earth,
3. Pure magneſia,
4. Fixed vegetable alkali,
5. Fixed mineral alkali,
6. Volatile alkali
7. Zinc,
8. Manganeſe
9. Iron,
10. Lead,
11. Tin,
12. Cobalt,
13. Copper,
14. Nickel,
15. Arſenic,
16. Biſmuth,
17. Mercury,
18. Silver,
19. Gold,
20. Platina,
21. Pure argillaceous earth,&
22. Water.

When animal ſubſtances in general, which have not undergone any fermentation or other change, are diſtilled, they firſt yield a phlegm, which is followed by an oil, which becomes gradually thicker, blacker, and empyreumatic; and is accompanied with a great deal of volatile alkali. When nothing more can be diſtilled over, there remains a coaly reſiduum like that which remains after the diſtillation of vegetable ſubſtances; but it muſt be obſerved, that from the animal coals no fixed alkali, or at leaſt an exceedingly ſmall quantity of it, can be obtained, when they are reduced to aſhes.

The bones of animals, by being kept in vinegar, or other diluted acids, become very ſoft; but they are entirely diſſoluble in ſtrong acids. Mr. NEUMAN, by diſtilling two ounces of ox-bone, obtained two drams of empyreumatic phlegm, one dram of volatile urinous ſpirit, two ſcruples of volatile alkali, two ſcruples of fetid oil, and one ounce, three drams, and two ſcruples of reſiduum.

Oil, whether of animal or vegetable ſubſtances, is a compound of water, acid, phlogiſton, and earth. It is not diſſoluble in water, or, at leaſt, in an exceeding ſmall degree; and is capable of burning with a vivid flame, attended with ſmoke and ſoot; leaving always a coaly reſiduum, which, as well as the ſoot, is very difficultly deprived of phlogiſton, and reduced into aſhes. Theſe elements of oils are found by diſtillation (for oil is volatile, though not ſo much as water) by combuſtion, and other means. By diſtilling oils ſeveral times repeatedly, always taking care to ſeparate them from the thick reſiduum, they may be attenuated ſo as to become very light, tranſparent, volatile, and penetrating. Beſides the action of fire, oils are alſo altered by expoſure to the air, and by other circumſtances; thus they become thick, rancid, empyreumatic, &c. according to their particular nature, and the alteration they undergo.

Acids in general, eſpecially when ſtrong, have a conſiderable action upon oils; generally occaſioning an ebullition, heat, vapours, a ſulphurous empyreumatic ſmell, and other effects, which vary according to the nature and proportion of the oil as well as of the acid. The action of ſome acids upon certain oils is ſuch, that even a flame and combuſtion of the oil is occaſioned by only mixing them; which is one of the moſt ſtriking experiments in chymiſtry. Thus, if about two drams of ſtrong nitrous and vitriolic acid, mixed together, be thrown at once upon about an equal quantity of any eſſential oil, for inſtance, oil of cloves, or of turpentine, contained in a large and flat veſſel, the mixture immediately ſwells, grows brown, emits fumes, and preſently burſts into a flame, which conſumes great part of the oil.

The animal oils, when firſt diſtilled, are very fetid; but by repeated diſtillations, they are attenuated, are rendered more clear, are deprived of their offenſive ſmell, and are reckoned a very good medicine for various diſeaſes.

When vegetable or animal ſubſtances, after having been expoſed to the action of fire for ſo long a time as is ſufficient to deprive them of all their volatile parts, and to reduce them into a black, brittle, and dry ſubſtance; they are then ſaid to be charred, or to be reduced into *charcoal**. This ſubſtance is very ſingular for its various properties, ſome of which have been very lately diſcovered. It is a ſign that a ſubſtance contains an oil, when it can be reduced into a coal; thus mineral bodies cannot be charred, but they may be reduced into a calx or glaſs, which are quite different things from coal.

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* The charcoal commonly uſed is made in the following manner:—Pieces of wood

A charcoal contains the phlogiſton of the decompoſed oil, combined with the earth and a ſmall portion of the ſaline principle belonging to the ſubſtance from which it was made.

Acids, alkalies, air, water, or other menſtruums, have no power upon charcoal; which, in ſhort, ſeems to be an indeſtructible ſubſtance, except it be burned in the open air, or its phlogiſton is made to paſs into other ſubſtances ready to receive it. Thus the vitriolic acid may acquire the inflammable principle from charcoal, and may form a ſulphur; metallic calxes may be revivified by acquiring the phlogiſton from charcoal, &c.: but in theſe caſes there is required the action of a ſtrong heat.

In cloſe veſſels charcoal may be made red hot, and may be kept in that ſtate for any length of time, without being ſenſibly altered. But in the open air it burns very eaſily, and ſeldom with any ſmall flame; becoming

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wood are formed into a pile, which is pretty well covered with earth, and they are ſet on fire. In this manner they burn ſlowly, but without flame, or at leaſt very little; and when they are ſufficiently charred, more earth is thrown upon the pile, which quite extinguiſhes the fire, and then the coals may be removed for uſe.

gradually red hot, but without any ſoot or ſmoke, till it is all reduced into aſhes *.

When coals are burning, an elaſtic fluid proceeds from them, which is exceedingly pernicious to animal life; ſo that various bad accidents have been occaſioned by burning coals in places where the air is confined. If a red-hot charcoal be extinguiſhed in a cloſe veſſel, or by immerſing it in quickſilver, it acquires the property of abſorbing a prodigious quantity of air, or of other elaſtic fluids, whenever it is made to touch them; but of the properties of charcoal, in regard to air and other elaſtic fluids, we ſhall treat at large in the courſe of this work.

CHAP. XI.

Of Fermentation.

FERMENTATION is a ſpontaneous inteſtine motion excited between the particles of moſt animal and vegetable ſuſtances, which changes their nature,

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* Some coals are much eaſier conſumed than others. This difference is ſenſible in charcoals of different ſorts of wood; but it is very remarkable between the coals of vegetable and thoſe of animal ſubſtances; it being very difficult to deprive animal charcoals of all their inflammable principle. Mr. MAQUER ſays, to have kept the coal of bullock's blood in a ſhallow crucible, quite red hot, expoſed to the air, and continually ſtirred for above ſix hours; and yet it was not reduced into white or even grey aſhes.

and exhibits new compounds out of their elementary principles. The agitation, decompoſition, &c. produced by the mixture of ſome mineral ſubſtances, either with bodies of the ſame claſs, or even with certain animal or vegetable ſubſtances, is called *efferveſcence*; thus malt, in order to make beer, muſt *ferment*; and a mixture of iron filings and acid of vitriol *efferveſces*.

In order to occaſion, or to promote fermentation in general, it is required, that the vegetable or animal ſubſtances contain a certain quantity of earth, and fluid oil, rendered ſoluble in water by the intervention of ſome ſaline matter; that they be diluted with a ſufficient quantity of water; that they be kept in a temperate degree of heat, as between forty-five and ſeventy degrees of Farenheit's thermometer; and laſtly, that the ambient air be not quite excluded from them. When vegetable or animal ſubſtances are put in theſe circumſtances; for inſtance, when grapes, juſt bruiſed, are put together with the liquor in a temperate degree of heat, they begin to ferment, viz. the liquor is agitated by an inteſtine motion, which is attended with heat, and a diſcharge of an elaſtic fluid *. This firſt fermentation gradually abates, and if the liquor be decanted in proper time, it will be found to be wine, which is an agreeable and ſpirituous liquor; hence this firſt fermentation is called the *vinous* or *ſpirituous fermentation*; but if this wine, either by itſelf, or together

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* The nature of this elaſtic fluid will be examined in other parts of this work.

gether with the conſiſtent parts of the grapes, is kept in circumſtances that favour fermentation, it will begin to ferment anew, till it becomes acid, or vinegar; and by a farther fermentation the ſubſtances are putrified: hence the Chymiſts have diſtinguiſhed three fermentations, namely, the *vinous*, the *acetous*, and the *putrid fermentations.* In regard to theſe different fermentations, or rather different ſtates of fermentation, it has been obſerved, that all thoſe ſubſtances, which are ſuſceptible of the vinous fermentation, may afterwards undergo the acetous and the putrid fermentation; that ſome ſubſtances are not capable of the vinous fermentation, but they begin with the acetous, and then paſs to the putrid; and laſtly, that ſome ſubſtances are capable of the putrid fermentation only.

Having remarked above, that fermentation requires ſome particular circumſtances in order to be effected, it may be eaſily underſtood, that the privation of thoſe favourable circumſtances hinders fermentation; ſuch are intenſe cold, want of air and water, and a diſproportion in the principles of the given ſubſtance; thus animal bodies may be preſerved from putrefaction by drying, by cold, by ſalt, and other means; wine is prevented from becoming vinegar, by being kept in a cold place, &c.

Omitting to mention the reſults of the various animal and vegetable fermentations, we ſhall only treat of the ſpirit of wine, which is a very uſeful and ſingular ſubſtance, and affords matter of much ſpeculation for the intelligent chymiſt.

Spirit of wine, or *ardent ſpirit*, is a very thin, very volatile, and colourleſs fluid, of a ſtrong penetrating ſmell and taſte, which by means of diſtillation can be obtained from all thoſe ſubſtances which have undergone the vinous fermentation, as wine, beer, &c. When the ſubſtances, from which the ſpirit of wine is to be extracted, are diſtilled, the ſpirit generally comes over with much watery fluid, from which it may be ſeparated by repeated diſtillations; viz. by putting the ſpirit obtained by the firſt diſtillation, into the diſtil by itſelf, and drawing over only a part of it, which will be found to be much purer; and which, by a ſimilar proceſs, may be purified ſtill farther; or, as it is commonly ſaid, may be *rectified.*

Spirit of wine is eaſily inflamed without being previouſly heated. In the open air it burns with a weak flame, which does not occaſion any ſmoke or ſoot, and when the ſpirit is ſufficiently pure it burns entirely, without leaving any reſiduum.

BOERHAAVE and JUNCKER affirm, that if ſpirit of wine be burned in proper veſſels capable to collect its vapours whilſt burning, theſe vapours will be found to be nothing but pure water; hence it appears, that ſpirit of wine contains a conſiderable quantity of water joined to the inflammable principle, and perhaps to ſome other ſubſtance beſides.

Spirit of wine has no ſenſible action upon earths, or upon metallic matters; but in general it diſſolves ſaline ſubſtances; excepting, however, moſt of the neutral ſalts. Some accurate experiments of Mr. Macquer, which determine the quantity of various ſalts that can be diſſolved in ſpirit of wine, and the appearance of its flame when different ſalts are diſſolved in it, are publiſhed in the Memoirs of the Academy of Turin. The principal reſults of thoſe experiments are exhibited in the following table *.

Quantity of grains.	Salts ſoluble in 288 grains of ſpirit of wine.	Appearances of the flame.
0	Vitriolated tartar,	None.
4	Nitre, — —	Flame larger, higher, more ardent, yellow, and luminous.
5	Salt of Sylvius, —	Large, ardent, yellow, and luminous.
0	Glauber's ſalt, —	Conſiderably red.
15	Cubic nitre, —	Yellow, luminous, detonating.
0	Common ſalt, —	Larger, more ardent, and reddiſh.
0	Vitriolic ammoniac,	None.
108	Nitrous ammoniac,	Whiter, and more luminous.

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* When in the table is found that the flame of the ſpirit has ſuch or ſuch other appearance, when the ſpirit does not diſſolve any quantity of the mentioned ſalt, it muſt be underſtood, that the ſpirit has been upon the ſalt, and afterwards has been filtrated, and then ſet on fire.

Quantity of grains.	Salts ſoluble in 288 grains of ſpirit of wine.	Appearances of the flame.
24	Sal ammoniac, —	None.
0	Selenites, —	None.
288	Nitre with calcareous baſis, —	Larger, more luminous, red, and decrepitating.
288	Marine ſalt with calcareous baſis, —	Like that of the calcareous nitre.
0	Vitriol of ſilver, —	None.
84	Nitre of ſilver.	
0	Luna cornea, —	None.
0	Vitriol of mercury,	None.
0	Nitre of mercury, —	None.
204	Corroſive ſublimate,	Large, yellow, luminous, and decrepitating.
0	Martial vitriol, —	None.
4*	Martial nitre, —	Red, and decrepitating.
36	Martial marine ſalt,	More white, luminous, and ſparkling.
0	Vitriol of copper, —	None.
48	Cupreous nitre,	More white, luminous, and green; much ſmoke. The ſaline reſiduum became black and burnt.
48	Cupreous marine ſalt,	Fine green, white, and red fulgurations.

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* Theſe 4 grains were an acid matter. This ſalt could not be dried without decompoſition.

Spirit of wine diſſolves eſſential oils and their concretions, as balſams, reſins, &c. for which reaſon it is of great uſe to extract the eſſential oils in the analyſis of vegetables; but it has no action upon fat oils, or the oily concretions analogous to them, as wax, butter, &c.; neither does it diſſolve copal and bituminous ſubſtances.

Spirit of wine may be mixed with water in any proportion; there being a conſiderable affinity between thoſe two ſubſtances. It is owing to this property, that ſpirit of wine coagulates the whites of eggs, and the animal lymph; that it preſerves matters from putrefaction; and that ſalts are inſtantaneouſly cryſtallized when ſpirit of wine is added to their ſolution in water. The mixture of ſpirit of wine and water is attended with a very remarkable phenomenon. This is a diminution of the quantity of the ingredients; thus, if fifty ounces meaſure of water are added to an equal quantity of ſpirit of wine, the mixture will be found to be ninety-eight ounces; hence, if a meaſure of ſpirit of wine weighing, for inſtance, three ounces, be mixed with one meaſure of water, weighing four ounces; afterwards one meaſure of the mixture, which might be expected to weigh three ounces and a half, will be found to be ſomewhat heavier than three ounces and a half; that is, the denſity of the mixture will be found to be increaſed above what might be expected by reaſoning upon ſimple mechanical principles. This increaſe of denſity varies according to the different proportions of the two ingredients; and as it is of ſome importance in philoſophy, as well as in œconomy, to know the real quantity of pure ſpirit contained in a given quantity of adulterated ſpirit of wine, I ſhall ſubjoin a table, which ſhows at one view the quantity of water, and of pure ſpirit, contained in adulterated ſpirit, as brandy, rum, &c. when its ſpecific gravity is accurately known. Thus, for inſtance, if we find upon trial, that the ſpecific gravity of the impure ſpirit is to the ſpecific gravity of pure water in the proportion of nine hundred forty-two and a half to one thouſand, we know, by the table, that this liquor contains equal parts of pure ſpirit and water; and that it contains only three parts of pure ſpirit, and thirteen parts of water, when its ſpecific gravity is to the ſpecific gravity of water as nine hundred and ſeventy-nine to one thouſand.

Spirit of wine.	Water.	Specific gravity.
16 parts.	0 parts.	837
15	1	852½
14	2	867⅓
13	3	881⅓
12	4	894½
11	5	907⅓
10	6	919⅔
9	7	931⅔
8	8	942½

Spirit of wine.	Water.	Specific gravity.
7 parts.	9 parts.	$951\frac{2}{3}$
6	10	$959\frac{2}{3}$
5	11	$967\frac{1}{4}$
4	12	$973\frac{1}{6}$
3	13	979
2	14	985
1	15	$991\frac{3}{4}$
0	16	1000

Alkalies, eſpecially when they are very ſtrong and dephlegmated, have a very conſiderable action upon ſpirit of wine, even decompoſing it when aſſiſted by a proper degree of heat. They firſt deprive it of its ſuperabundant water, and laſtly, reduce it into the ſtate of a true oil.

Acids of every ſort may be combined with ſpirit of wine; by which combination the acids as well as the ſpirit ſuffer conſiderable alterations. When the mixture of acid and ſpirit of wine is diſtilled, a portion of much dephlegmated ſpirit is firſt obtained; then a thinner fluid comes over, called *ether*, which is different from ſpirit of wine, for ſeveral peculiar properties, to be mentioned preſently; and laſtly, a real oil is diſtilled.

Ether acquires different appellations from the different acids which have been employed in making it, as *vitriolic ether*, *nitrous ether*, *marine ether*, &c. Its principal properties are the following:—It is a tranſparent, colourleſs fluid, much lighter than any other known viſible fluid; its ſmell is much more penetrating than ſpirit of wine; it is alſo much more volatile [*], and more inflammable than ſpirit of wine, but its flame is attended with a little ſlight ſmoke or ſoot.

Ether is not miſcible with water, except in a very ſmall degree, as about one part of ether may be diſſolved in ten parts of water, and even that is ſlowly and difficultly effected. On account of theſe properties, ether ſeems to be a ſubſtance exactly intermediate between ardent ſpirits and oils.

Ether, like other thin and volatile inflammable matters, acts powerfully on the nerves, for which reaſon it has been often uſed in medicine as a ſedative and antiſpaſmodic. It poſſeſſes the diſſolving property in a more eminent degree than ſpirit of wine. The vitriolic ether, eſpecially, diſſolves all eſſential and expreſſed oils, animal empyreumatic oils, reſins, and in great meaſure even ambergriſe, elaſtic gum or *caoutchouc*, petroleum, and oil of amber. Ether is very uſeful to take off ſpots of greaſe from ſilks, as it does not injure their colours.

Ethers formed with different acids have ſome properties peculiar to each, which principally relate to their colour, ſtrength, and ſmell; the proceſſes for making them are alſo different; but for a particular account of them the reader muſt conſult the writings of chymical authors, eſpecially Mr. Macquer's Dictionary of Chymiſtry.

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[*] Ether is ſo very volatile, that when it is put under the receiver of an air-pump, and the air is exhauſted, it expands almoſt inſtantaneouſly into an inviſible fluid, which by preſſure may be again reduced into ether.

CHAP. XII.

Deſcription of a Chymical Laboratory, and of Chymical Operations.

CHYMISTRY being a ſcience, which by actual experiments examines the nature, properties, and components of various ſubſtances; and forms new compounds out of divers principles; it does neceſſarily require a ſet of proper inſtruments, and of various ſubſtances, the uſe of which occurs more frequently in chymical operations. It is alſo requiſite that thoſe inſtruments, &c. be kept in a convenient place, called a Laboratory, where the various required proceſſes may be carried on, and where the effects of ſome operations may not occaſion any diſagreeable accident, as would more often be the caſe, if they were conducted in a cloſe room of a private apartment. In this chapter we ſhall only give a ſummary account of ſuch an apparatus, and its uſe, as is juſt ſufficient for a philoſophical chymiſt, who does not require to make any large operations, ſuch as are neceſſary for commerce.

The Laboratory ſhould be a room ſufficiently large, and rather dry and airy. It ſhould have windows at oppoſite ſides, which might be eaſily opened, in order to ventilate it, and to expel any offenſive effluvia, which in ſome proceſſes, and eſpecially by unforeſeen accidents, are often thrown about the laboratory. It ſhould alſo have a pipe of water very near, for the convenience of waſhing, &c. and a place wherein uſeleſs matters may be thrown.

A ſufficiently large chimney muſt be conſtructed in the laboratory, under which two or three furnaces muſt be built, a couple of ovens, and a place muſt be left beſides where portable furnaces may be occaſionally placed; the chimney therefore ſhould be conſiderably extenſive. In ſome laboratories the chimney reaches from one wall to another.

It is neceſſary to keep a wide open box filled with dry ſand, in which hot veſſels, or ſuch veſſels as have a round bottom, may be placed. In ſome laboratories there is a place built on purpoſe to keep the ſand. The furnaces principally neceſſary, ſome of which muſt be built under the chimney mentioned above, are the following:

The *ſimple furnace*, which is a kind of hollow cylinder, having an iron grate horizontally acroſs the middle, upon which the fire is made; and two openings, viz. one below the grate, called the *door of the aſh-hole*, and the other above the grate, called the *door of the fire-place*, through which, when any veſſel is upon the furnace, the coals muſt be introduced; and alſo a poker to ſtir the fire, if required. This furnace is very uſeful for diſtillations, decoctions, &c.

The *lamp furnace*, which is nearly ſimilar to that deſcribed above; but it has no aſh-hole nor grate, for here the heat is only maintained by a lamp, which is introduced through an opening below. A ſmall kind of chimney is made laterally in the upper part of the furnace, ſo as to let the air circulate, and to keep the lamp burning. This furnace is of great uſe when a gentle heat is only required, particularly becauſe the lamp can burn for a long time without any aſſiſtance.

The *reverberatory furnace* is thus deſcribed by Mr. Macquer: "Is the *ſimple furnace*, the fire-place of "which is covered with a piece of the ſame diameter "and form as the furnace, which is generally cylindrical. "This piece is croſſed in its lower part by two bars of "iron placed horizontally, and parallel to each other, and "at its upper edge it has a ſemi-circular cut. This piece "conſequently forms a third cavity, which is called the "*Laboratory*, becauſe it is intended to receive the retorts "containing the matter to be diſtilled. The ſemi-circular cut is made to give paſſage to the neck of the re-"tort, which ought to be inclined at an angle of forty-"five degrees. The uſe of the two bars at the bottom of

" the laboratory is to ſupport the veſſel placed there. " Above the piece we have now deſcribed, is a fourth " piece placed, the form of which is that of a ſpherical cap, " or of an inverted dome: it is accordingly called the " *dome*. This dome has an equal diameter to the other " piece to which it is to be fitted; and in its lower edge " it has a ſemi-circular cut, which correſponds with the " ſimilar cut of the lower piece; and theſe together form " a circular opening: the dome has in its top another " opening or ſhort tube, through which the air contained " in the furnace paſſes, and is a kind of chimney.

" The uſe of the dome is to keep up the heat all around " the retort which is placed in the furnace, and to apply " a certain degreee of heat to the upper part or vault of " the retort, by reflecting or reverberating it: hence it is " called a *reverberatory*. By this diſpoſition the vapours " which riſe in the retort are determined more efficaci" ouſly to paſs through its neck. We may judge, after " this deſcription, that reverberatory furnaces are only " uſed for diſtillations with a retort, in which a certain " degree of heat is neceſſary."

The *melting furnace*, ſo called from its being uſeful to melt metals, is ſo conſtructed, that a ſtrong current of air paſſes conſtantly through the fire-place, conſequently the fire is increaſed to a great degree. To this effect the cavity of the furnace under the grate is made rather conical, the ſmalleſt part being uppermoſt, and next to the grate.

This furnace is only open at the top, through which opening, coals and crucibles are introduced; and it communicates with the chimney tranſverſely.

A ſtronger fire, when required, muſt be aſſiſted by a double bellows, a large pair of which ſhould always be found in a laboratory.

The other inſtruments, beſides furnaces, are the following, viz. *Alembics*, either of glaſs or of copper; and *retorts*, which are made of iron-earth, but more commonly of glaſs; which alembics and retorts ſerve for diſtillations.

Glaſs bodies, or *receivers*, which ſerve to receive the produce of diſtillations, and to cool heated liquors.

Crucibles, which are earthen veſſels, repreſenting the inverted fruſtrum of a cone. The form, and moſtly the ſize of theſe veſſels vary according to the different uſes for which they are to be employed, that is for melting metals, purifying, calcining them, reducing their calxes, &c.

Open veſſels, and bottles of various ſizes and forms, for digeſtions, mixtures, diſſolutions, for preſerving various ſubſtances, &c.

Funnels of glaſs and of tin, for decanting and filtrating liquors.

Glaſs tubes, ſpatulas, tongs, paper not ſized, for filtrations, a portable pair of bellows, exact ſcales for weighing, tables, ſtands, a good ſteel for ſtriking fire, and for trying the hardneſs of certain ſubſtances, a magnet, and various other articles which a ſhort experience will ſoon ſuggeſt.

Beſides the inſtruments, the laboratory ſhould be furniſhed with various ſubſtances and preparations, which, by being daily uſed, may be conſidered as inſtruments. Such are the three mineral acids, viz. the vitriolic, the nitrous, and the marine acid. Some good diſtilled vinegar. Alkaline ſalts, and oil of tartar. Some dry and ſome liquid liver of ſulphur, kept in well-cloſed bottles. Quicklime, and lime-water, alſo kept in well-cloſed bottles. Spirit of wine well rectified. Oil of turpentine. Metals and ſemi-metals of every ſort. Common ſalt. Oil of olives. Soap: and other articles of the like ſort.

As the limits of this Introduction do not allow me to expatiate upon the uſe of the various chymical inſtruments, and the manner of conducting the operations in general; I ſhall only deſcribe the uſe of retorts for diſtillations, becauſe they are of great uſe in the ſubject of elaſtic fluids, which is the principal object of this work. As for the other chymical operations, the reader may find ſufficient inſtructions in various books of chymiſtry.

Fig. the firſt of plate I. repreſents a retort, the part of which, A, B, C, is called the body of the retort, into which the materials to be diſtilled are put, through the opening E of the neck D, which is the only opening of the retort. The neck D is always bent, in the manner repreſented by the figure; from which curvature the inſtrument derives its name.

Now, when any ſubſtances are to be diſtilled with the retort, the ingredients are put in through the opening E, till they fill about half the body of the retort; afterwards a receiver is adapted to the neck of the retort, in the manner repreſented in fig. 2, and then the inſtrument is ready to be put over the fire. The neck R of the receiver G, is ſometimes fitted ſo well to the neck of the retort, that it is not neceſſary to put any thing elſe to it in order to hinder the diſſipation of vapours; but if it ſhould not fit ſo well, then moiſtened rags, cotton, clay, or ſome other ſimilar thing, may be put round the juncture. H is a ſmall hole, through which the fluid diſtilled may be taken out of the receiver, and which, eſpecially when the juncture K of the two necks is very well cloſed, muſt be frequently opened in order to promote the diſtillation; for when the acceſs of the ambient air is accurately excluded, the diſtillation cannot be performed. The fire that is adapted to the retort muſt be different, according to the different nature and volatility of the matters that are diſtilled. Sometimes the heat of a lamp is ſufficient; at other times the retort, if made of glaſs, is luted all round the body with ſoft clay, or other ſuch-like lutum, and is put upon a pretty ſtrong fire; and ſometimes the whole body of the retort, and alſo part of its neck, are ſurrounded with burning coals into a reverberatory furnace. In this caſe only iron or earthen retorts are uſed. In general, for common diſtillations, a pan filled with dry ſand, called *ſand bath*, is put upon the fire, and the bottom of the glaſs retort is placed in it, ſo that the body of the retort may be ſurrounded with ſand as high as A B.

The receiver G ſhould be defended as much as poſſible from the heat of the fire, and it ſhould be ſupported by a proper ſtand I, over which ſomething ſoft is placed, as a mat, a piece of cloth, a hollow circular cuſhion, or the like.

Now when the heat begins to be communicated to the matter contained in the body A, B, C, of the retort, the vapours, conſiſting of the more volatile and ſpirituous ſubſtances, aſcend as high as the top F of the retort, where they are determined along the neck D, into the receiver G; but as the neck D, and receiver, are much colder than the body of the retort, theſe vapours are condenſed in their paſſage, and drop from the neck of the retort into the receiver, wherein they appear in the form of a fluid.

Having already deſcribed the principal chymical properties of natural bodies, and the changes they undergo in various circumſtances, the ingenious reader will, perhaps, be capable to perform by himſelf ſeveral experiments without any farther more particular inſtructions, eſpecially if he will take the trouble to perform ſome of the proceſſes to be deſcribed in the next chapter, which will be related with all the neceſſary circumſtances.

Suppoſe, for inſtance, that it was required to examine the heterogeneous ſubſtances contained in any mineral water, whoſe nature is unknown. Firſt, by evaporation, one may eaſily know if it contains any ſalts or earthy particles; for theſe will remain in the veſſel when the water is evaporated. By the taſte it may be known whether it contains any conſiderable quantity of acid; but if the portion of acid ſuſpected to exiſt in that water is very ſmall, ſo as not to be diſcerned by the taſte, then other means ſhould be uſed. Now if we read over the properties of acids in general, given in the preceding chapters, we find that a ſmall portion of acid is capable of turning into red the blue tincture of flowers; hence, diſſolving a ſmall quantity of extract of heliotropium, or other blue vegetable extract, in diſtilled water, and throwing this ſolution into the mineral water, will ſoon ſhew if any acid is contained in it, as it was ſuſpected; for in that caſe, the water will aſſume a reddiſh appearance. In the ſame manner one may find out any other matter contained in that water, viz. by carefully conſidering the properties of the ſuſpected ſubſtances, and deviſing proper methods to manifeſt their preſence.

Before we conclude this chapter, the reader ſhould be cautioned not to be ſurpriſed if he fails in performing any experiment, either deſcribed at length in this Introduction, or deducible from the mentioned properties of natural bodies; the circumſtances concurring to the ſucceſs of any experiment in chymiſtry, being ſo many, that they can hardly be minded by the moſt experienced practitioner, and may therefore more eaſily eſcape the notice of a beginner.

ginner. Miſtakes and perſeverance will warn the experimental philoſopher againſt many uſeleſs and dangerous practices, and will gradually enable him to examine the powers of nature, and to perform the experiments with dexterity and preciſion.

CHAP. XIII.

Containing various Chymical Proceſſes.

THIS Introduction being intended as a neceſſary preliminary to the ſubject of air, and other permanently elaſtic fluids, the preſent chapter contains the detail of proceſſes and experiments moſtly ſubſervient to that intereſting branch of natural philoſophy: there are added, however, a few others, which, although not immediately relating to that ſubject, are yet moſtly new and diverting; for which reaſon they were thought deſerving the attention of the reader.

I. *To make Lime-water.*

Diſſolve ſome pure and freſh quicklime in diſtilled water. Let part of this ſolution be filtrated through unſized paper, and keep it for uſe in well-corked bottles. It is a property of lime-water to become turbid, and to depoſit the lime in form of calcareous earth, when a particular ſort of elaſtic fluid comes into contact with it; for which reaſon it is of great uſe to diſcover the preſence of that elaſtic fluid in various caſes.

II. *To make Liver of Sulphur.*

Let equal parts of fixed alkali and ſulphur be melted in a crucible over the fire. This fuſion ſhould be made rather quick, in order to avoid the diſſipation of the ſulphur; but yet the fire needs not be very ſtrong, becauſe as ſoon as the ſulphur is melted, it facilitates the fuſion of the alkali. When the mixture is perfectly fuſed, let it be poured upon a greaſed marble ſtone, where it will ſoon congeal, and acquire a browniſh colour. Then it muſt be broken in pieces, and muſt be put in a bottle whilſt yet hot. As the liver of ſulphur imbibes the moiſture from the air, the bottle ſhould be accurately ſtopped, if it is required to preſerve it dry.

Liver of ſulphur, in the humid way, may be made in the following manner:—Let flowers of ſulphur and concrete liquid fixed alkali be boiled together, till the alkali has diſſolved as much ſulphur as it can. Then let the liquor be filtrated and evaporated, &c.

III. *To inflame Regulus of Antimony by means of Aqua-regia.*

Let a common vial, ſuch as apothecaries more commonly uſe, be about half filled with aqua-regia, made with four parts of nitrous and one part of marine acid. Theſe acids ſhould be very ſtrong. Then take powdered regulus of antimony, and drop it gradually upon the aqua-regia; keeping the hand that holds the powder a few inches above the vial. It will be found that the particles of regulus take fire, and ſparkle like a flint and ſteel, before they touch the ſurface of the aqua-regia, viz. by only paſſing through its vapours.

IV. *To make* Hemberg's *Pyrophorus.*

Mix together one part of ſugar and three parts of alum; and let this mixture be melted and dried in an iron ſhovel over the fire, till it becomes a dark brown or blackiſh powder. In this operation it muſt be often ſtirred with an iron ſpatula. Any large pieces of this coaly matter muſt be bruiſed into a powder, and then muſt be put into a glaſs matraſs * or vial, having a long neck, and rather narrow than large. This matraſs muſt then be placed in a crucible, or other earthen veſſel, large enough to contain the body of the matraſs, and about half an inch beſides all round it, which ſpace is to be filled with dry ſand. This apparatus muſt then be put into the fire, which muſt be raiſed gradually, till the whole becomes red hot, in which ſtate it muſt be kept for about one hour, or till a quarter of an hour after that a weak ſulphurous flame has begun to appear at the mouth of the matraſs. The apparatus is then to be removed from the fire, and the moment that it loſes its redneſs, the mouth of the matraſs muſt be ſtopped with a cork, and when the whole is ſufficiently, though not quite cold, the matraſs muſt be taken out of the crucible, and the pyrophorus it contains, which is a blackiſh, moſtly granulated powder, muſt be decanted into a dry phial, which muſt afterwards be kept exactly ſtopped, in order to preſerve the pyrophorus for a long time. The principal properties of this ſubſtance are the following:—As ſoon as a ſmall quantity (ſometimes a few grains of it are enough) of it is expoſed to the open air, it quickly becomes red hot, and is capable of ſetting fire to paper, tinder, &c. If the air, and the ſubſtance upon which the pyrophorus is dropped, are very dry, the accenſion is ſlowly, and ſometimes not at all effected; but it may be promoted by breathing upon it; which ſhows, that the pyrophorus requires moiſture as well as the preſence of air, in order to take fire. If the bottle is not cloſed very well, the pyrophorus will imbibe the moiſture by ſmall degrees, ſo as to loſe its burning property in a ſhort time. After combuſtion, the pyrophorus, or rather its aſhes, will be found to be increaſed in weight. Although alum and ſugar were directed above to be uſed for making the pyrophorus, yet it may be made with other matters, though perhaps not ſo well, nor with ſo much certainty; for the neceſſary and principal ingredients are the vitriolic acid and phlogiſton; hence it may be made with any vitriolic ſalt beſides alum, and almoſt any other ſubſtance capable of furniſhing the inflammable principle, beſides ſugar.

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* A *matraſs* in Chymiſtry ſignifies a veſſel nearly in the ſhape of a common vial; although their form is not conſtant.

V. Dr. HIGGINS's *Experiment of detonating cupreous Nitre by contact with Tin.*

This experiment, ſhewing the violent action of the nitrous acid upon tin, ſufficient to occaſion a detonation, is thus deſcribed in the ſixty-third volume of the Philoſophical Tranſactions.

" Several pieces of thin ſheet copper, placed vertically, " and at a ſmall diſtance from each other, in the ſtrong " nitrous acid, diluted with half its quantity or more of " water, and ſuffered to remain in a cloſe veſſel until the " acid is ſaturated, afford a cryſtalline bluiſh green ſalt, " which is to be ſeparated from the undiſſolved and the " ſuperfluent green liquor, and kept in a well-corked " bottle; becauſe, on expoſure to air, it deliqueſces.

" This ſalt taken moiſt, but not very wet, and beaten

“ to the fineneſs of baſket ſea-ſalt, in a mortar, is to be
“ ſtrewed to the thickneſs of a ſhilling on a piece of tin-
“ foil, twelve inches in length, and three in breadth.

“ Then the foil is to be inſtantly rolled up, ſo as to
“ include the ſalt as it lay between the coils. The ends
“ are to be ſhut by pinching them together, and the
“ whole is to be preſſed flat and cloſe.

“ All this being done as quick as poſſible, the firſt
“ phenomenon is, a part of the ſalt deliqueſces. 2. This
“ part, impregnated with tin changed in colour, and of a
“ thicker conſiſtence, begins to froth forth from the ends
“ of the coil. 3. A ſtrong frothing, accompanied with
“ moderate warmth. 4. The emiſſion of copious nitrous
“ fumes. 5. Heat intolerable to the fingers. 6. Ex-
“ ploſion and fire, which burſt and fuſe the tin-foil in
“ ſeveral places, if it be very thin.

“ After many experiments and conjectures, I diſcovered
“ a property in the cupreous ſalt, from which, and the
“ known affinities of the bodies concerned, theſe appear-
“ ances may be accounted for.

“ The cupreous ſalt properly dried, and placed where
“ it can receive a heat not much greater than what the
“ hand can bear, takes fire. The circumſtances which
“ favour this ignition, and contribute to produce it in the
“ ſmalleſt degree of heat, concur in the following conve-
“ nient method of trying the experiment:

“ A piece of ſoft bibulous paper is to be dipped in the
“ nitrous

" nitrous ſolution of copper, and dried before the fire " two or three times alternately. Then it is to be approached towards the heat, as near as can be borne by " the hand which holds it without pain; there, if it has " been ſufficiently dried, it will preſently catch fire, and " burn to a brown calx. The eaſy ignition of the ſalt in " a ſlight heat being thus aſcertained, there is no room " to doubt that the foregoing phenomena are produced " in the following manner:

" The acid of the liquor which moiſtened the ſalt quits " the copper to unite with the tin, leaving the water to " be imbibed by the contiguous ſalt of copper, which then " diſſolves, and acts briſkly upon the tin-foil. It is well " known, that the action of the nitrous acid on tin is always accompanied with conſiderable heat and efferveſcence, and that the ſolution of metallic ſalts in watery " liquors is haſtened by heat.

" In our experiment, the warmth generated by the " firſt action of the cupreous ſolution promotes the deliqueſcence of the cryſtallized ſalt. The union of the " acid with the tin is rapid, not only as being aſſiſted, " but on account of the great ſurface expoſed; whence " the ſtrong frothing, and the extraordinary heat, by " which the redundant moiſture is carried away, and the " undecompoſed part of the cupreous ſalt, together with " that lately formed with the tin, perfectly dried.

" The heat generated upon both ſurfaces of a large

" expanſe of tin, is concentrated by cloſely coiling it into " a ſmall compaſs, and, being retained by the various ſur- " rounding laminæ of metal, it is neceſſarily accumulated " to a quantity; which, if we may judge from the touch, " is more than ſufficient to fire the dry cupreous ſalt.

" The ſalt formed with tin, and the nitrous acid, burns " and ſparkles in a red heat. Catching fire, therefore, " from the ignited cupreous ſalt, it burns with it, and " aſſiſts in the detonation, which is common to all nitrous " compoſitions in ſimilar circumſtances.

VI. *To make Mr.* CANTON'*s calcareous Phoſphorus.*

Calcine ſome oyſter-ſhells for about half an hour in a clear fire. Such old ſhells as are found upon the ſea-ſhore are much preferable for this purpoſe. Let the pureſt part of this calx be powdered and ſifted, and mix three parts of this powder with one part of flowers of ſulphur. This mixture muſt be rammed into a crucible about one inch and a half deep, till it is almoſt full, and then it muſt be kept red hot in the fire for one hour at leaſt; after which time it may be removed from the fire and left to cool. When cold, the lump of matter is taken out of the crucible, and being broken in pieces, it is expoſed to the light of the day, and is immediately brought into a dark room, where it will ſhine; but ſome parts of it, which are the brighteſt, muſt be ſeparated from the reſt, and kept in a well-cloſed bottle.

This phoſphorus being kept in the dark, ſhews no light; but if it is expoſed to the light, and then brought into a dark place, it will be found to ſhine for ſeveral minutes. Its light is at firſt ſo ſtrong, that a ſmall quantity of it may enable a perſon to diſtinguiſh the hour on a watch. This phoſphorus preſerves its property for ſeveral years, if it is kept free from moiſture. For farther particulars relating to the properties of this phoſphorus, ſee the Philoſophical Tranſactions, Vol. LVIII.

VII. *To make Vitriolic Ether.*

Pour two pounds of concentrated vitriolic acid at once upon two pounds of well-rectified ſpirit of wine, contained in a glaſs retort. The vitriolic acid, on account of its greater ſpecific gravity, will ſink to the bottom. Let the retort be often ſhaken gently, ſo as to mix the two liquors; which will ſoon become very hot, and boil; vapours iſſuing from it with a loud hiſſing noiſe, and a pleaſant penetrating ſmell. Now the retort muſt be put in a ſand-bath, gradually warmed to the ſame degree of heat. Lute a receiver to it, having a ſmall hole on one ſide; and make ſuch a fire under the retort as will keep the liquor boiling rather quickly. The firſt produce of the diſtillation is a very ſweet ſpirit of wine, after which follows

lows the ether, which is diſtinguiſhed by ſtriæ formed on the upper part and neck of the retort. This diſtillation muſt be continued with the ſame degree of heat, till on applying the noſtrils to the ſmall aperture on the ſide of the receiver, which, during the diſtillation, muſt be frequently opened, a ſuffocating ſmell of volatile ſulphurous acid is perceived. The receiver then being unluted, will be found to contain a mixture of a very dephlegmated part of the ſpirit of wine, of ether, of a little oil, and ſometimes alſo of a ſmall portion of ſulphurous acid. In order to ſeparate the ether from the other ſubſtances, this compound liquor muſt be put into a glaſs retort, and muſt be diſtilled with a gentle degree of heat on a lamp furnace, till half of the whole quantity is come over into the receiver, which is the ether, and muſt be preſerved in a bottle accurately ſtopped.

VIII. *To make* KUNCKEL'*s Phoſphorus.*

" In order to make phoſphorus by Mr. MARGRAAF's proceſs, a kind of plumbum corneum is previouſly prepared, by diſtilling a mixture of four pounds of minium with two pounds of powdered ſal ammoniac, from which all the volatile alkali, which is very penetrating, is by this operation obtained. The reſiduum after the diſtillation, that is, the plumbum corneum, is to be mixed with nine or ten pounds of extract of urine boiled to the conſiſtence of honey. Mr. Margraaf requires, that this urine ſhould be putrified, which is unneceſſary, according to Mr. Beaume's obſervation. This mixture is to be made ſlowly, in an iron cauldron ſet upon the fire, and frequently ſtirring the matters. Half a pound of powdered charcoal is then to be added, and evaporation is to be continued till the whole is reduced into a black powder. This powder is to be put into a retort, to extract from it, by a moderate and graduated heat, all the volatile products of urine, that is, volatile alkali, fetid oil, and an ammoniacal matter which adheres to the neck of the retort. In this diſtillation, the heat is to be only raiſed ſo as to make the matter red hot. After the diſtillation, a black and friable reſiduum remains, from which the phoſphorus is to be extracted by a ſecond diſtillation, and a ſtronger heat. Before it is expoſed to another diſtillation, it may be tried, by throwing ſome of it upon hot coals. If the matter has been well prepared, a ſmell of garlic exhales from it, and a blue phoſphorical flame is ſeen undulating along the ſurface of the hot coals.

" This matter is to be put into a good earthen retort, capable of ſuſtaining a violent fire. Mr. Margraaf recommends retorts of *Waldenbourgh*, or thoſe which are made near *Kirchan* in Saxony; which not being known in France, Heſſian retorts are uſed there, although they have the inconvenience of allowing a large quantity of phoſphorus to tranſpire during the operation. Mr. Beaume ſecures his retorts with a covering of clay and hair.

"Three quarters of the retort are to be filled with the matter which is to yield the phoſphorus. It is to be placed in the common furnace for diſtillation with a retort; excepting that, inſtead of being terminated by an ordinary reverberatory or dome, this ought to be terminated by the upper piece of an air-furnace, to which a tube is to be applied, the diameter of which ought to be from four to ſix inches, according to the ſize of the furnace; and the height from eight to nine feet. This apparatus, which Mr. Beaume uſes, is neceſſary for raiſing a ſufficient heat, and for the convenience of throwing in a ſufficient quantity of fuel through the door of the upper piece of the furnace. The retort ought to be well luted to a receiver of moderate ſize, pierced with a ſmall hole, and half full of water. For this purpoſe, ordinary fat lute may be bound on with ſtripes of linen, dipped in a lute prepared with lime and whites of eggs. The hole in the furnace, through which the neck of the retort paſſes, ought to be well ſtopped with furnace earth. Laſtly, a ſmall wall of bricks is raiſed betwixt the furnace and receiver, to guard this veſſel againſt heat as much as is poſſible.

"All theſe preparations being made the evening before the diſtillation is to be performed, we are then capable of proceeding to this operation, which is very eaſy. The retort is to be heated by ſlow degrees during an hour and a half; and then the heat is to be increaſed till the retort be red-hot, and the phoſphorus begins to paſs in luminous vapours: when the retort is almoſt of a white red heat, the phoſphorus paſſes in drops, which fall and congeal in the water at the bottom of the receiver. This degree of heat is continued till no more paſſes into the receiver. When a retort contains eight pints or more, this operation continues about five hours.

" Mr. MARGRAAF's apparatus is ſomewhat different from that above deſcribed. He divides the whole quantity of matter, from which the phoſphorus is to be obtained, into ſix ſmall retorts, which he places in a furnace that he deſcribes. The advantage of this diviſion is, that if any accident happens to one retort, the whole matter is not loſt; and as the retorts are ſmaller, a leſs heat is required. If indeed much phoſphorus was to be made, this practice would be ſafe and excellent; but I can affirm, that the method above deſcribed, of Mr. BEAUME, is very convenient when a large quantity of phoſphorus is not wanted, and that I have never ſeen it fail.

" Phoſphorus does not paſs pure in this diſtillation, but is blackened by ſoot or coal, which is carried along with it: it may be eaſily purified, and rendered white and fine, by a ſecond diſtillation or rectification. This rectification is made in a ſmall glaſs retort, to which is adjuſted a ſmall receiver half full of water. A very gentle heat is ſufficient, becauſe phoſphorus once formed is very volatile;

and, as the fuliginous matters with which it is ſoiled were raiſed merely by the violence of the heat, they remain at the bottom of the retort in this diſtillation, and the phoſphorus paſſes very pure.

"The phoſphorus is then uſually divided into ſmall cylindrical rolls, for the conveniency of uſing it. This is done by putting it in glaſs tubes immerſed in warm water. This very gentle heat is ſufficient to liquefy the phoſphorus, which is almoſt as fuſible as ſuet. It takes the form of the glaſs tubes; from which it may be taken out when it is cold and hardened. That it may be more eaſily taken out of the tubes, theſe muſt be ſomewhat of the form of fruſtrums of cones. All theſe operations ought to be made under water, to prevent the inflammation of the phoſphorus *."

Whenever this phoſphorus is taken out of the water, it ſhines with a conſiderable light; emitting luminous white fumes, which have a ſtrong and diſagreeable ſmell of urine. Letters and other things may be drawn with this ſubſtance upon the wall, or any other place, which will ſhine for a conſiderable time; but in performing theſe experiments the operator muſt take to keep the phoſphorus only for a very ſhort time out of the water, and alſo to rub it very gently when he draws with it; for a ſtrong friction, as well as a moderate heat, will inflame it, in which caſe it burns with great violence, emitting ſtrong ſuffocating vapours, accompanied

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* MACQUER's Dictionary of Chymiſtry.

with a very vivid flame. From this it appears, that this phoſphorus has two kinds of flame, viz. One weak emanation of light, by which it ſhines in a dark place, and is conſumed by very ſmall degrees; and another ſtrong flame, which burns it in a few ſeconds.

If a few grains of phoſphorus be put in about half an ounce of ether, it will be diſſolved in two or three days at moſt, and the ether then acquires the property of ſhining in the dark; ſo that if the bottle containing it be opened, and a few drops of it be ſpread upon the palm of the hand, or any other place, they will give a light ſtrong enough to diſcern the hour of a watch. In this experiment there is no fear of the phoſphorus taking fire, and burning with a ſtrong flame, as when it is not diſſolved. Beſides ether, the phoſphorus may be diſſolved in any eſſential oil.

If a ſmall piece of the phoſphorus be rubbed between two pieces of paper, it will preſently take fire, and inflame the paper. One grain of it is enough to make this experiment. It is almoſt ſuperfluous to mention, that ſeveral of the above-mentioned experiments with KUNCKEL's phoſphorus muſt be performed in the dark. This phoſphorus was, till very lately, procured only from urine. But Mr. SCHEELE, an excellent Chymiſt, has diſcovered, that the ſaline matter called *phoſphoric acid*, is contained copiouſly in the earth of the bones of animals. Mr. MACQUER, however, obſerves, that the ſaline phoſphoric matter obtained from bones, although proper for making the phoſphorus, is nevertheleſs, in ſome reſpects, different from that acid which remains after the combuſtion of phoſphorus.

The beſt method of obtaining this ſaline matter from bones has not yet been perfectly deſcribed. Mr. ROVELLE ſays, that a greater quantity of phoſphoric ſalt may be obtained from uncalcined than from calcined bones. It has been extracted from hartſhorn, calcined to whiteneſs by means of vitriolic acid, and alſo from other bones; but the hartſhorn hitherto ſeems to furniſh the largeſt quantity of it, three or four ounces being yielded from one pound of hartſhorn. This ſaline ſubſtance is at firſt of the conſiſtence of ſyrup; but by evaporating it to dryneſs, and melting it in a crucible, it becomes a vitreous matter; which being mixed, and diſtilled with powder of charcoal in the manner deſcribed above, produces a very fine phoſphorus.

From the experiments hitherto made with bones, in order to extract the phoſphoric acid, &c. it has been deduced, that the earth of bones is eſſentially a calcareous earth, forming a ſelenites with the vitriolic acid, and calcinable into quicklime, after it has been ſeparated from the vitriolic acid by means of a fixed alkali, and well waſhed.

IX. *To make Fulminating Powder.*

This powder is made by mixing together three parts of nitre, two parts of ſalt of tartar, and one part of ſulphur. When a ſmall quantity of this powder, for inſtance, a drachm of it, is put into an iron ſpoon over the fire, it melts, becoming gradually brown, ſwells, and at laſt it explodes with a ſurpriſing violence and noiſe. It is remarkable, that this powder does not require to be confined, like gunpowder, in order to make a great exploſion; and alſo that it requires a ſlow application of heat, ſo as to be firſt fuſed; for if the fire be applied ſuddenly, the fulmination is leſs violent. If this powder, when melted, be removed from the fire the very moment before it explodes, it is then in ſuch a ſtate, as it explodes like gunpowder, and even ſtronger, whenever an ignited body is approached to it. But for this experiment the compoſition is beſt made with three parts of nitre, two of ſulphur, and one of ſalt of tartar. This mixture muſt be put upon a ſhovel over the fire, and muſt be kept ſtirring till it is melted, when it muſt be removed, and kept in a well-corked bottle. In this ſtate it is ready to take fire like gunpowder by a match, and to explode with conſiderably greater violence; but it is ſoon deprived of its property by the leaſt moiſture.

In corking the bottle that contains this powder, care ſhould be taken that none of it be left in the neck of the bottle; for the friction of the cork may be capable of inflaming it.

PART

PART II.

Containing the principal Properties of elaſtic Fluids, and the Deſcription of the Apparatus neceſſary to make Experiments on that Subject.

THE various branches of natural philoſophy are ſo intimately connected with one another, that it is next to impoſſible to advance, or even to underſtand properly any particular ſubject, without having a competent knowledge of other collateral and ſubſervient branches. For this reaſon, a ſhort Introduction to Chymiſtry has been prefixed to the preſent work, whoſe principal object is to exhibit a view of the preſent ſtate of diſcoveries relating to the chymical nature and properties of air, and other permanently elaſtic fluids. But Chymiſtry, although the principal, is not the only ſcience neceſſary to underſtand thoroughly, and to advance this ſubject. A competent knowledge of Hydroſtatics, of Electricity, and of the principles of Mathematics, are alſo requiſite.

However, in the following pages we ſhall only make a ſhort mention of Hydroſtatics, viz. of the preſſure and equilibrium of fluids, which is neceſſary for the management of the experiments to be mentioned hereafter; referring thoſe readers, who are not acquainted with the other ſciences, to the Treatiſes written expreſsly upon them.

The properties of elaſtic fluids to be mentioned in this Part, muſt not be conſidered to be all their properties hitherto diſcovered; a full account of them all, and of the uſes to which they may be applied, being reſerved for the third Part; but they are thoſe properties which the beginner may more eaſily experience, in order to learn the uſe of the apparatus, and which ſerve as an introduction to the third Part; in which we ſhall treat of all the properties of each particular ſort of elaſtic fluid in ſeparate chapters, which will thereby be rendered more perſpicuous and conciſe. Suppoſe, for inſtance, that the properties of common air were to be treated of; it would be neceſſary to mention the remarkable diminution of this atmoſpherical fluid occaſioned by the addition of another permanently elaſtic fluid, commonly called *nitrous air*; viz. that when theſe two kinds of elaſtic fluids are mixed together, their joint bulk is much leſs than the ſum of both their quantities, and alſo that this diminution is greater or leſs according as the nitrous air is more or leſs pure, &c. Now here it muſt be ſuppoſed, that the properties of nitrous air have been previouſly mentioned; but this is impracticable

ticable, for ſimilar reaſons, viz. becauſe a previous knowledge of the nature of common air muſt be neceſſarily premiſed. It is therefore neceſſary to mention in this Part a few of the principal properties of air, and other permanently elaſtic fluids, without entering into a minute detail of them all, in order to render the third Part of this work more perſpicuous, and leſs verboſe.

If the reader wiſhed to become really acquainted with the ſubject, it is neceſſary that he ſhould perform at leaſt the experiments to be mentioned in this Part, ſo as to learn all the principal properties of elaſtic fluids, before he paſſes to read the third Part, which would otherwiſe be little underſtood.

In reſpect to the names of the elaſtic fluids, a great variety of them may be found amongſt the writers on the ſubject. Some authors give the name *air* to the common atmoſpheric fluid only, and call the other elaſtic fluids *gaſes* *; thus, *nitrous gas*, *vitriolic gas*, *calcareous gas*, &c. This method certainly ſeems to be the moſt rational, becauſe the other elaſtic fluids, being eſſentially different from common air, require particular names. But others have given the name *air* to them all: thus *nitrous air*, with them, is the ſame thing as the above-mentioned *nitrous gas*, *fixed air* is the ſame as *calcareous gas*, &c.

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* The word *gas* is derived from the German *gaſcht*, or *gaſt*, which ſignifies an eruption of wind, or the frothy ebullition which accompanies the expulſion of elaſtic fluids from fermenting and effervefcing ſubſtances.

That ſome of theſe names are improperly given to the things they are meant to denote, is certainly true; to call, for inſtance, *fixed air* an elaſtic fluid, which is moveable by the leaſt agitation, rarefaction, condenſation, &c. is very abſurd; and to give it the ſpecific name *air*, when it has no chymical property in common with the reſpirable air, is evidently improper: but at laſt, names are only words, by which we diſtinguiſh one thing from another, and conſequently they are always uſeful if they anſwer that purpoſe. They may be grammatically improper, and they might be changed for better; but grammatical improprieties, when they don't confuſe the expreſſions in which they are uſed, are not to be minded in natural philoſophy. Were I the firſt, or the principal writer on this ſubject, it would in that caſe be incumbent on me to adopt ſuch names as are leſs exceptionable: but when the ſubject is pretty well known in the philoſophical world, to adopt any new or leſs-uſed names, would be certainly diſpleaſing and perplexing to an ear otherwiſe accuſtomed. I hope therefore to be excuſed, if in the courſe of this work ſome names of elaſtic fluids ſhould be uſed, which, although commonly mentioned by ſome ingenious authors, and generally uſed in common philoſophical diſcourſe, yet are a very proper ſubject for criticiſm. Nevertheleſs, all the various names uſed by writers of note will be mentioned in proper places, ſo that they may not be new to the reader, when he meets with them in the books written on this ſubject.

CHAP. I.

Of Hydroſtatics.

THE ſcience which treats of the preſſure and equilibrium of fluids, or of their mechanical properties, has been called *Hydroſtatics.*—This word indeed ſeems to confine the ſcience to water only; but as the mechanical properties of fluids of every ſort are the ſame, allowance being made for the differences ariſing from their ſpecific gravities and elaſticity, it is of no conſequence whether they are inveſtigated principally with water, or with any other fluid.

The firſt law of Hydroſtatics is, *that fluids of every ſort gravitate in their proper places, and their preſſure is propagated according to every direction,* i. e. *downwards, upwards,* and *ſideways.* The upper parts of any fluid continually preſs upon the lower ones, and fluids of different ſpecific gravities, as oil, water, ether, air, mercury, &c. when put into a common veſſel of any ſhape, gravitate upon each other, the lighter upon the heavier, and the heavier upon the lighter; and their preſſure is propagated in every poſſible direction; ſo that the ſides, as well as the bottom of a veſſel containing any fluid, or mixture of fluids, ſuſtain a conſiderable preſſure. But thoſe properties will be evidently demonſtrated by the following eaſy experiments.

The firſt part of the above-mentioned propoſition, in plainer language, ſignifies, that if a quantity of water, for inſtance, a cubic inch of it, when weighed with a pair of ſcales, is found to be equal to one ounce, the ſame quantity, either at the top, in the middle, or in any other part of a large veſſel filled with water, or any other fluid, will always be of the weight of one ounce; and that preſſure of one ounce will be ſuſtained by the fluid under it, or by the bottom of the veſſel. In order to prove this aſſertion, let any ſtopped glaſs bottle, heavy enough to ſink in water when empty, have a ſlender ſtring tied to its neck, one end of which ſtring muſt be faſtened to the arm of a balance; and let the bottle be weighed very accurately. Suppoſe its weight to be nine ounces. Then let the bottle be wholly immerſed in a large veſſel full of water, as it is repreſented in fig. 3, Plate I. and weigh it again whilſt it is ſtill empty. In this caſe the bottle will appear to be lighter than when it was weighed in the open air, for reaſons which will appear preſently. Suppoſe that in this ſecond caſe its weight be found to be equal to two ounces. Now fill the bottle with water, and replace the ſtopper; then add ſome weight into the ſcale of the balance (for now the bottle will be much heavier than when it was empty) ſo as to balance it and keep it about the middle of the veſſel C D E F, or in ſhort, not touching the bottom or ſides of it. Suppoſe the weight of the bottle filled with water to be nine ounces. Now if the water contained in that bottle be weighed in the open air, it will be found to weigh ſeven ounces. This may be tried, either by pouring the water contained in the bottle, in the ſcale of a balance, or ſimply by taking the bottle B out of the veſſel C D E F, and weighing it in the open air, where it will be found to weigh ſixteen ounces; nine ounces of which are the weight of the bottle as it was found at firſt, which being ſubtracted from ſixteen, there remains ſeven ounces for the weight of the water; which demonſtrates, that the quantity of water contained in the bottle B, has the ſame weight, when ſurrounded with the ſame fluid, as when weighed in the open air *.

From this law it follows, that if a body of any ſort be immerſed in water, and weighed after the manner deſcribed in the above-mentioned experiment, its weight will be juſt the difference between its weight when weighed in the open air, and the weight of a quantity of water, whoſe bulk is equal to the bulk of the ſaid body. Thus, if a cubic inch of metal weighs ten ounces in the open air, and a cubic inch of water, or of any other fluid, weighs only one ounce; when that piece of metal is ſuſpended like the bottle B, by means of a ſlender ſtring A, B, to the arm of a balance, and is weighed in that fluid, its weight will be found to be nine ounces; which is the difference be-

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* In this experiment a proper allowance ſhould be made for the weight of the air contained in the bottle when firſt weighed, which air eſcapes when the bottle is filled with water. But as the difference is very trifling, it may be as well neglected.

tween its weight when weighed in the open air, and the weight of an equal bulk of water, or of that other fluid tried.

It is plain, that if a ſolid body, immerſed in any fluid, is lighter than an equal bulk of that fluid, the ſolid body will ſwim on the ſurface of it, and if it is heavier, it will ſink to the bottom; for in every combination of bodies the heavieſt will always occupy the loweſt parts, except they are hindered to take that place, which is not the caſe with fluids, when ſolids are freely and wholly immerſed in them. But if the weight of the ſolid body is equal to an equal bulk of the fluid, then the body will remain in every part of it where it is left, viz. near the ſurface, or in the middle, &c.

A box or boat may be made of any of the metals, which are much heavier than water; ſo as to ſwim in that fluid. Suppoſe, for inſtance, that a cubic box of metal, one inch every way, be made ſo thin, that its weight is leſs than that of a cubic inch of water; it is plain, that this metal box, when immerſed in water, muſt ſwim near the top of it; becauſe the bulk of the water that it diſplaces, weighs more than the box itſelf. But ſuppoſe that this metal box be filled with water, and immerſed in it; then it will immediately ſink, becauſe in this caſe it no longer diſplaces a cubic inch of water, but only ſuch a quantity of it as it is equal to the thickneſs of its ſides; which quantity being lighter than the metal of the box, it neceſſarily follows that the box muſt ſink.

When the weights of equal bulks of different ſubſtances are compared together, they are called ſpecific gravities, or ſpecific weights; thus, gold is ſaid to be ſpecifically lighter than ſilver, becauſe a cubic inch of the former weighs 10 ounces, 7 pennyweights, 3.83 grains; whereas a cubic inch of the latter weighs only 5 ounces, 11 pennyweights, 3.36 grains.—Water is ſaid to be ſpecifically lighter than mercury, becauſe the weight of a cubic inch of the former is about 10 pennyweights; and the weight of a cubic inch of the latter is 7 ounces, 7 pennyweights, 11.61 grains; and ſo of the reſt. Now, from the above-demonſtrated principle, we deduce a method of finding out the ſpecific gravities of bodies, without taking the trouble of meaſuring exactly a cubic inch, or any other meaſure of the ſame. The method is as follows:—The given body being ſuſpended to one arm of a balance, by means of a very fine ſtring, as a ſilk thread, a hair, &c. is firſt weighed in air, and afterwards in water, then, ſubtracting the latter weight from the former, the remainder will ſhew the weight of the given body over that of an equal bulk of water. Thus, if a guinea is firſt weighed in air, it will be found to be 129 grains, and when weighed in water will be found to be 121¾ grains, which being ſubtracted from 129, there remains 7¼ grains, which is the weight of a quantity of water equal to the bulk of the guinea. Therefore the ſpecific gravity of ſuch gold as is employed to make guineas, is to the ſpecific gravity of water as 129 to 7¼; or by dividing 129 by 7¼ (or, which is the ſame, by 7.25) and comparing the quotient to *one*, is as 17.793 to 1, viz. that ſort of gold is nearly eighteen times heavier than water. After the ſame manner, by trying any piece of fine ſilver, the ſpecific gravity of it is found to be 11.087, viz. to be about eleven times heavier than water; and, compared to the ſpecific gravity of gold, it appears to be much lighter than that metal.

In ſhort, the method conſiſts in finding out the weight of the given body in air, then its weight in water, and laſtly in dividing the firſt weight by the difference between the firſt and ſecond weight, the quotient of which diviſion ſhews how many times the given body is heavier than water. In this manner a table of the ſpecific gravities of various bodies is made. But it is plain, that from what has been ſaid above, only the ſpecific gravities of ſolid bodies that are heavier than water may be found out; but two other caſes ſhould be conſidered, viz. when the ſpecific gravities of divers fluids, and when the ſpecific gravities of bodies lighter than water are to be aſcertained.—Firſt, when the ſpecific gravity of a fluid is required to be known, for inſtance, of wine; take a piece of any ſolid ſubſtance, that is not diſſoluble in wine or water, and by the method mentioned above find its ſpecific gravity with reſpect to water; then repeating the experiment with wine inſtead of water, find the ſpecific gravity of that body with reſpect to wine, which will evidently ſhew the ſpecific gravity of wine, viz. how much heavier or lighter it is than water; for ſuppoſe that the ſolid body tried weighs two, three, four, or more times in wine than in water, it ſhews that the wine is two, three, four, or as many more times lighter than water.—The body generally uſed to find out the ſpecific gravities of fluids is a glaſs ball, or a lump of glaſs nearly in the ſhape of a pear, becauſe glaſs is not attacked by acids in general, and is heavy enough to ſink in any liquor, excepting quickſilver.

When the ſpecific gravity of mercury, and alſo of ſome ſmall ſolid ſubſtances, as grains of platina, fragments of diamonds, &c. are to be tried, which cannot be conveniently tied to a thread, and even if they were to be tied to a thread, the weight of the thread or hair being conſiderable in reſpect to the weight of thoſe ſmall bodies, would occaſion a very ſenſible error: in thoſe caſes, therefore, the beſt method is to put the ſubſtances to be tried in a glaſs bucket. Thus, ſuppoſe that the ſpecific gravity of quickſilver is required to be known; let the empty glaſs bucket be firſt weighed in air, then pour the quickſilver in it, and weigh it again. Let both thoſe weights, viz. that of the bucket and that of the quickſilver, be noted. Now take away the quickſilver from the bucket, and weigh the latter by itſelf in water, viz. intirely filled and ſurrounded with water; then pour the ſame quantity of quickſilver that was uſed before, into the bucket whilſt ſtanding in water, and add as much weight into the ſcale as will balance the bucket with the quickſilver; which will ſhow the weight of the quickſilver in water; which being ſubtracted from its weight in air, the remainder is the weight of a quantity of water equal in bulk to the quickſilver: by which remainder divide the weight of the quickſilver in air, and the quotient ſhows how much the quickſilver is heavier than water.

When the ſolid body, whoſe ſpecific gravity is required to be known, is lighter than water; ſuppoſe, for inſtance, it be a piece of cork; it is plain, that if the cork be left under water, it will ſoon ſwim to the ſurface: but take a heavy body, as a piece of lead, or, in ſhort, ſuch a body as, when tied to the piece of cork, or other light body to be tried, may ſink with it in water; and let this heavy body be weighed in water after the manner mentioned above, then tie the piece of cork to it, and weigh them again in water, in which caſe they will be found to be lighter than the heavy body alone. Suppoſe that the heavy body, when weighed alone, was found to weigh ten ounces, and when weighed together with the cork or other body, their weight was found to be only nine ounces; it is plain, that the piece of cork is one ounce lighter than an equal bulk of water. Now let this piece of cork be taken out of the water, be dried, and weighed in air by itſelf, where ſuppoſe it be found to weigh one quarter of an ounce; it is evident, that a quantity of water equal in bulk to this piece of cork, or other body, weighs one ounce and a quarter, becauſe, as we ſaid above, the piece of cork is one ounce lighter than an equal quantity of water; conſequently, that piece of cork, or other body, is five times lighter than water, or, which is the ſame thing, a quantity of water equal in bulk to the piece of cork weighs five times as much as the cork, or other body tried.

As the ſpecific gravities of various bodies are neceſſary to be known, in order to deduce proper conſequences from ſeveral experiments, to be mentioned hereafter, I ſhall ſubjoin a ſhort Table of the ſpecific gravities of thoſe bodies, which may more often occur in our experiments, as well as in common philoſophical and œconomic occurrences.

A Table *of ſpecific Gravities.*

A cubic inch of	Avoirdup. weight.		Comparative weight.
	Oz.	Drachms.	
Very fine gold, - -	11	5.80	19.637
Standard gold, - -	10	14.90	18.888
Guinea gold, - -	10	4.76	17.793

Quickſilver,

A cubic inch of	Avoirdup. weight.		Comparative weight.
	Oz.	Drachms.	
Quickſilver, - -	8	1.45	14.019
Lead, - - - -	6	9.08	11.325
Fine ſilver, - - -	6	6.66	11.087
Standard ſilver, -	6	1.54	10.535
Copper, - - - -	5	1.89	8.843
Plate braſs, - - -	4	10.09	8.000
Steel, - - - -	4	8.70	7.852
Iron, - - - -	4	6.77	7.645
Block tin, - - -	4	3.79	7.321
Zinc, - - - -	4	1.42	7.065
Glaſs of antimony, -	3	0.89	5.280
German antimony,	2	5.04	4.000
Diamond, - - -	1	15.48	3.400
Clear glaſs, - - -	1	13.16	3.150
White marble, - -	1	9.06	2.707
Rock cryſtal, - -	1	8.61	2.658
Green glaſs, - -	1	8.26	2.620
Cornelian ſtone, -	1	7.73	2.568
Flint, - - - -	1	7.53	2.542
Native ſulphur, -	1	2.52	2.000
Nitre, - - - -	1	1.59	1.900
Alabaſter, - - -	1	1.35	1.875
Dry ivory, - - -	1	0.89	1.825
Alum, - - - -	0	15.72	1.714
Ebony, - - -	0	10.34	1.117
Human blood, - -	0	9.76	1.054
Amber, - - -	0	9.54	1.030
Cow's milk - -	0	9.54	1.030

Sea-

A cubic inch of	Avoirdup. weight. Oz.	Drachms,	Comparative weight.
Sea-water, - - -	0	9.54	1.030
Pump-water, - -	0	9.26	1.000
Spring-water, - -	0	9.25	0.999
Diſtilled water, -	0	9.20	0.993
Proof ſpirits, - -	0	8.62	0.931
Dry oak, - - -	0	8.56	0.925
Olive oil, - - -	0	8.45	0.913
Oil of turpentine, -	0	7.33	0.772
Cork, - - - -	0	2.21	0.240

In this Table pump-water has been conſidered as the ſtandard, to which the ſpecific gravities of various ſolids and fluids are compared; the ſpecific gravity of pump-water is therefore conſidered to be 1, and the numbers of the ſame, viz. of the laſt column, ſhew the ſpecific gravities of the bodies againſt which they are marked; thus we find, that German antimony is four times heavier than pump-water, that alum is only ſeven hundred and fourteen thouſand parts of a time heavier than water, &c.

Some ſubſtances, eſpecially thoſe which are obtained by art, and are much compound, vary conſiderably in their ſpecific gravities. Such are the metallic ores, the mineral acids, wines, &c.; hence their ſpecific gravities cannot be properly expreſſed in tables; but whenever it is neceſſary to know the ſpecific gravity of any ſubſtance of that ſort,

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the experiment ſhould be tried with the very ſame ſpecimen in hand.

It muſt be obſerved, that even the ſpecific gravities expreſſed in the table are ſubject to ſome error and variation. Even when the ſubſtances are very homogeneous and pure, and the experiments are performed very accurately, a ſenſible difference or error may be occaſioned by a different degree of temperature; for bodies in general are contracted by cold, and expanded by heat, and theſe expanſions and contractions are by no means proportionate to their ſpecific gravities.

In order to return to the hydroſtatic propoſition mentioned toward the beginning of this chapter, it is neceſſary to demonſtrate by experiments that fluids preſs not only downwards, but alſo ſideways, and, in ſhort, in every direction whatever. The meaning, as well as the truth of this aſſertion, will be better underſtood by the following experiments.

A B C D, fig. 4, repreſents a deep tub full of water; E, F, G, H, I, are glaſs tubes open at both ends, whoſe lower extremities, excepting that of E, are variouſly bent. The tubes E, H, and I, ſhould have a capillary bore; the others may be of any diameter whatever. Now dip the lower extremity of the capillary tube E into quickſilver, ſo that a ſmall quantity of that fluid may enter in it.—This ſmall quantity of quickſilver will remain in the tube, although the tube ſhould be taken out of the cup containing the quickſilver *. This done, let the tube E, containing a ſmall quantity of quickſilver near its lower orifice, be dipped into the water of the tub A B C D, and the quickſilver *a b*, which, when the tube was out of the water, reſted near its lower aperture, will now aſcend farther up, as it is ſhewn by the figure; and the lower the tube is immerſed, the higher the quickſilver will aſcend, being impelled by the water; which ſhews that the water contained in the tub preſſes upwards as well as downwards. If the ſame experiments be tried with the other tubes F, G, H, I, viz. a ſmall quantity of quickſilver be introduced into their lower extremities, and then be dipped in water, it will be clearly perceived, that the water in the tub preſſes not only downwards or upwards, but in every poſſible direction; for the quickſilver will always be puſhed backwards from the orifices of the tubes, however they may be inclined.

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* Whenever one extremity of a glaſs tube having a ſmall bore, viz. not greater than half an inch, and open at both ends, is immerſed in water, the ſurface of the water within the tube will be found to be conſiderably higher than the ſurface of the ſurrounding water. This height is greater when ſmaller, and leſs when larger tubes are uſed; it being in the inverſe proportion of the diameters of the tubes: thus, if the ſurface of the water within a given glaſs tube is one inch above the level of the ſurrounding water, the height of the water within another tube, whoſe diameter is half that of the former, will be two inches. This aſcent, &c. is more or leſs obſervable with other fluids alſo, and is owing to the attraction exiſting between glaſs and the particles of fluids. It is commonly known under the name of *capillary attraction*, becauſe with tubes that have a very ſmall bore, like a hair, this ſuſpenſion of water or other fluids is very conſpicuous; it amounting to ſeveral inches.

The reaſon why the tubes E, H, and I, muſt have a capillary bore, is, that the quickſilver might not drop out of them, but might be ſuſpended in virtue of the capillary attraction.

From theſe obſervations it follows, that when a perſon dives in water, that fluid preſſes upon every part of the ſurface of his body, and not only upon thoſe parts which happen to be upwards; and alſo, that if a ſtopped empty bottle, being very thin and eaſy to be broke on one ſide only, be dipped in water, it is in equal danger of being broke by the preſſure of the water, whether the weak part be put downwards, upwards, or in any other ſituation.

If the above-mentioned experiments be repeated when the tub A B C D is filled with any other fluid inſtead of water, or with a mixture of different fluids, as oil, water, ſpirit of wine, &c. the ſame effects will be obſerved, only more or leſs, viz. the preſſure will be greater or leſs, according to the various ſpecific gravities of the fluid employed.

The ſecond hydroſtatical propoſition is, *that fluids preſs according to their perpendicular altitudes, whatever their quantities may be, or however the veſſels that contain them may be figured.* Thus, if the bottoms B C, and F G, of two veſſels A B C, and D E F G, fig. 5, are equal, and the veſſels are filled equally high both with water, or any other fluid; viz. the perpendicular heights of the fluid in both veſſels are equal; the bottom B C, of the veſſel A B C, will ſuſtain an equal degree of preſſure with the bottom F G, of the other veſſel, notwithſtanding that the veſſel D E F G may perhaps contain ten or twenty times as much water as the veſſel A B C.

In order to demonſtrate this propoſition, ſuppoſe that the ſtraight-ſided veſſel A B C D, fig. 6, ſtanding perpendicular upon a table, be filled with water as far as its middle E F; the bottom C D, in that caſe, will ſuſtain the preſſure occaſioned by the weight of that water. But if the veſſel be quite filled, by pouring as much more water in it, then it is plain that the bottom will ſuſtain a preſſure greater than it did before, and exactly the double of that. Thus, if this veſſel was ſuppoſed to be much higher, and equal portions of water were ſucceſſively poured in it, the bottom C D would ſuſtain degrees of preſſure exactly proportional to thoſe quantities of water, and to the perpendicular heights of the water; for in this caſe, viz. when the ſides of the veſſel ſtand perpendicular, equal quantities of water will fill equal perpendicular heights of the veſſel.

Now ſuppoſe that the two equally high veſſels G H E F, and I K N O, fig. 7, quite filled with water, had their bottoms EFNO, equal to one another, and were ſet upon an horizontal table. I ſay, that the bottom E F, of the veſſel G H E F, ſuſtains as much preſſure as the bottom N O, of the veſſel I K N O; viz. that if the preſſure upon the bottom E F, is equal to 20lb. weight, the preſſure upon the bottom N O, is alſo equal to 20lb, although the veſſel I K N O, contains many times more water than the veſſel G H E F.—From the extremities I, K, of the mouth of the larger veſſel, drop the two perpendicular lines I L, K M, to meet the extended bottom N O, in L and M; and alſo from the extremities N and O of the bottom riſe the perpendiculars N P, O Q, to touch the ſurface of the water: then ſuppoſe, that the veſſel I K N O is changed into the ſtraight-ſided veſſel I K L M, wholly filled with water. In this caſe it is plain that the portions L N, N O, O M, of the bottom will each ſuſtain the preſſure of their reſpective perpendicular colums of water, viz. L N ſuſtains the preſſure of the pillar of water I P L N; N O ſuſtains the preſſure of the pillar of water P Q N O; and O M ſuſtains the preſſure of Q K O M. Now, if we imagine that the part L N of the bottom is changed into I N, it is plain, that this alteration will not change the preſſures on the other parts N O, O M, of the bottom; ſo that in this caſe N O will ſuſtain the ſame degree of preſſure it did before; and the water I P N will preſs upon I N.—The ſame thing may be ſaid of the part O M of the bottom, viz. it may be conceived to be changed into K O, &c. So that N O, howſoever large may the top I K be, does always ſuſtain the preſſure of a column of water, whoſe baſe is equal to N O, and whoſe perpendicular height is P N, that is, the perpendicular height of the water contained in the veſſel.

In the other caſe, viz. of the veſſel G H E F, draw the four perpendicular right lines AE, BF, CG, DH, from the extreme points of the bottom, and of the mouth of the veſſel, and ſuppoſe, that the veſſel G H E F is changed into the veſſel A B E F, intirely filled with water. In this caſe it is plain, that the bottom E F ſuſtains the preſſure of the column of water ABEF, equal to PQNO; for we ſuppoſed above, that E F was equal to N O, and that the perpendicular height of the water in both veſſels was alſo equal, viz. GC equal to PN.—Now that the preſſure upon the bottom EF is the ſame when the water ABEF, or GHEF, is upon it, may be underſtood by imagining, that in the firſt caſe the parcels of water AGE, and HBF, are the ſides which confine the water GHEF; for any parcel of water may be conceived to be kept in by the reſt of the water, which every way ſurrounds it, as in a veſſel. By the ſame way of reaſoning we may conclude, that the water contained in any veſſel, however irregular, preſſes upon the bottom with a force equivalent to the column of water, having the ſaid bottom for its baſis, and the perpendicular height of the water for its altitude.

From this principle the following corollaries may be deduced. I. That in veſſels which have an equal bottom, and the perpendicular heights of fluid of the ſame ſort, contained in each, are equal; the preſſures upon their bottoms are alſo equal. II. That in veſſels that have equal bottoms, and unequal perpendicular heights of fluid of the ſame ſort, the preſſures upon their bottoms are in the proportion of thoſe perpendicular heights; ſo that if the perpendicular height of the fluid in one veſſel is double, treble, &c. that of the other, the preſſure upon its bottom will be reſpectively twice, thrice, &c. as great as the preſſure ſuſtained by the bottom of the other veſſel. III. That in veſſels whoſe bottoms are unequal, but contain an equal perpendicular depth of fluid of the ſame ſort, the preſſures ſuſtained by their bottoms are in the proportion of the ſurfaces of the ſaid bottoms. IV. That in veſſels having unequal bottoms, and containing unequal perpendicular depths of fluid of the ſame ſort, the preſſures ſuſtained by their bottoms are to one another in the compound ratio of the reſpective perpendicular depths of the fluid, and of the ſurfaces of the ſaid bottoms; thus, if the bottom of a veſſel A is twice as large as the bottom of another veſſel B, and the perpendicular height of the fluid in A is equal to three times that of the fluid in the veſſel B; the preſſure ſuſtained by the bottom of A will be ſix times greater than that ſuſtained by the bottom of the veſſel B. V. Laſtly, in veſſels having unequal bottoms, containing fluids of different ſpecific gravities, and of different depths; the preſſures ſuſtained by their bottoms are to one another in the compound ratio of the ſpecific gravities of the fluids, of the perpendicular heights of thoſe fluids, and of the ſurfaces of the reſpective bottoms. Thus, if a veſſel A contains a fluid half as heavy as that contained by another veſſel B, if the perpendicular height of the fluid in A is equal to four times the perpendicular height of the fluid in B, and the bottom of A is half as large as the bottom of B, the preſſures ſuſtained by the ſaid bottoms are equal.

We ſhall now ſhew the truth of this propoſition (viz. that fluids preſs according to their perpendicular heights) by experiments. Take a glaſs tube of about one inch or more in diameter, open at both ends, and let it be bent in the ſhape repreſented by ABE, fig. 8; then, holding it with the arched part downwards, pour ſome water into it, ſo as not to fill it intirely. The water will aſcend in each leg to the ſame level CD. Now in this experiment one may ſay, that the water riſes to the ſame level in each leg, becauſe it is counterbalanced by an equal quantity of water in the oppoſite leg; but in order to ſhew that the water in one leg riſes to the ſame level with that in the other leg (becauſe then they balance each other by their equal perpendicular heights, and not by their quantities) let the experiment be repeated with another bent tube, one leg of which is many times wider than the other, like that repreſented fig. 9, and it will be found that the water will aſcend to the ſame level in both legs of this tube, as well as it did in the legs of the tube fig. 8. Now it is plain, that if fluids preſſed by their quantities, the ſurface of the water in the leg C of the tube fig. 9, ought to be much higher than the ſurface of the water in the oppoſite leg; becauſe the quantity of water contained in the leg A, being many times greater than that of the other leg, ought to preponderate, and puſh the water in that other leg upwards; but the water, or any other ſingle fluid, in each leg comes to the ſame level; therefore fluids preſs according to their perpendicular heights.

From this it appears, that if pipes that communicate together are ever ſo oddly ſhaped, as they are repreſented fig. 10, the water, or other fluid that is put into them, will riſe to the ſame level in each pipe.

When fluids of different ſpecific gravities, and that do not mix and incorporate together, are put in ſuch circumſtances as to balance each other, then their preſſures muſt be eſtimated, not only from their perpendicular heights, but alſo from their ſpecific gravities. Take a glaſs tube, fig. 11, ſhaped like that in fig. 8 or 9, it being of no conſequence whether one leg of it be equal or wider than the other, and pour ſome quickſilver in it, which will riſe to the ſame level CD in each leg, for reaſons ſhewn above; but if ſome water be poured in one leg, for inſtance B, of this tube, the quickſilver, in conſequence of this, will not riſe in the oppoſite leg A to the ſame level with the ſurface of the water in the leg B, but it will reſt about E, and its other ſurface reſts about F in the leg B, whilſt the water occupies the ſpace FG; its ſurface G being much higher than the ſurface E of the quickſilver in the leg A. The reaſon of this is, becauſe the quickſilver is much heavier than water, and as its ſpecific gravity is to the ſpecific gravity of water as 14 to 1 nearly, it follows, that a column of quickſilver is balanced by a column of water fourteen times higher; accordingly it will be found, that the column of water G F is fourteen times higher than the column of quickſilver EH*.—If inſtead of water, ſome other fluid lighter than water, as oil, ſpirit of wine, &c. was poured upon the quickſilver into the leg B, its column G F would be ſtill greater in proportion to the column E H of quickſilver. In ſhort, the perpendicular height G F of one fluid, is to the perpendicular height EH of the other fluid (meaſuring theſe heights always from the level HF, where the ſurfaces of thoſe two fluids touch each other) in the inverſe ratio of their ſpecific gravities. Thus, if the ſpecific gravity of the fluid in the leg A is to the ſpecific gravity of the fluid in the leg B as *a* to *b*, the perpendicular height of the former is to the perpendicular height of the latter, viz. EH is to GF, as *b* to *a*.

From this experiment the judicious reader may eaſily deduce a method of finding the ſpecific gravities of divers fluids.

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* This column muſt be eſtimated from E to the level HF of the ſurface F of the quickſilver in the other leg B.

CHAP. II.

A View of the Preſſure of Fluids actually exiſting in Nature.

IN the preceding chapter we treated of Hydroſtatics in as compendious a manner as ſeemed conſiſtent with perſpicuity; ſhewing the principal laws of that ſcience, by means of ſuch reaſoning and experiments as could be underſtood and performed by perſons unacquainted with mathematics, and not much verſed in experimental philoſophy. But in the preſent chapter we ſhall conſider the force, laws, and effects of the natural preſſure of fluids, eſpecially of the atmoſpherical air, which gravitates with an immenſe weight upon the ſurface of our terraqueous globe, and in conſequence of which preſſure the greateſt part of the phenomena continually obſerved, do exiſt. A perſon not converſant with natural philoſophy will undoubtedly wonder, when he hears that his body is continually preſſed by a weight of many hundred pounds; and his admiration will be much increaſed, when he is told, that ſhould that preſſure be removed, it would prove his immediate death.—But the reaſon of our not feeling any pain from that enormous weight, the laws of its variations, and other effects, will be ſhewn in the ſequel.

The whole ſurface of the earth, together with the animals, plants, and in ſhort every thing that exiſts thereon, are ſurrounded by an inviſible fluid called *air*, in the ſame manner as the fiſhes, aquatic plants, &c. that are in the ſea, are ſurrounded by water. The aquatic bodies are continually preſſed by the water; which preſſure is more or leſs, according to the perpendicular height of the water above them; and after the ſame manner bodies out of the water are continually preſſed by the weight of the air, which weight varies according to the air's perpendicular height, and other cauſes to be mentioned hereafter. A fiſh in the ſea is not preſſed downwards more than it is upwards by the weight of the ſuperincumbent water, becauſe the preſſure of fluids, as we ſaid above, is propagated in every direction; and that preſſure cannot ſqueeze the fiſh inwardly, becauſe the fluids of the body of that animal counteract it: ſo that the fiſh, and every thing elſe thrown into the ſea, cannot fall to the bottom, except it is ſpecifically heavier than ſea-water. In the ſame manner an animal upon the ſurface of the earth is neither preſſed towards the earth, nor feels any pain from the preſſure of the ſuperincumbent air, becauſe that preſſure is exerted on every ſide, and is counteracted by the air within the body; ſo that an animal is preſſed as much downwards, as he is preſſed upwards by the weight of the air, and the ſurface of his body is preſſed inwardly by the preſſure of the ambient air, as much as it is preſſed outwardly by the internal air and other fluids. Hence, if an animal, or any thing elſe, left free in the air, falls to the ground, it falls only becauſe it is ſpecifically heavier than air. Was it ſpecifically lighter, it would aſcend upwards; and this is the reaſon why ſmoke, and other light bodies, aſcend into the air, viz. becauſe they are ſpecifically lighter than air. But ſuppoſe that the air was exhauſted from a large veſſel, and then by ſome means a quantity of ſmoke was introduced into the veſſel; the ſmoke in that caſe would fall to the bottom of the veſſel; in the ſame manner as a piece of cork, which being left in the middle of a tub, would aſcend when the tub is full of water, and would fall to the bottom when the tub is empty.

From this principle it follows, what in fact is eaſily proved by experiments, viz. that bodies of every ſort appear to be heavier in vacuo than in air; for inſtance, if a piece of metal, or any other matter, weighs one ounce in air, it will weigh ſomething more than one ounce when weighed under the exhauſted receiver of an air-pump; for bodies in air gravitate with only the difference between their real weights and the weights of ſuch quantities of air as are equal to their own bulks, in the ſame manner, and for the ſame reaſons, by which bodies weigh leſs in water than in air.

The whole maſs of air which ſurrounds the earth, together with the clouds, and other bodies that float in it, is called *atmoſphere.* In order to render the preſſure of the atmoſphere ſenſible, the counteraction of that preſſure muſt be removed from one ſide of a body proper for the experiment. Thus, if one end of a glaſs tube, open at both ends, be immerſed in water, or any other liquor, the ſurface of the liquor within the tube will be at the ſame level with that of the liquor without (excepting the difference which may be occaſioned by the capillary attraction, in caſe tubes having a ſmall bore are uſed) becauſe the atmoſphere preſſes alike upon the water within as upon that out of the tube; but apply the lips to the other extremity of the tube, and ſuck the air out of it; then the liquor will immediately riſe within the tube, becauſe ſome of the air being exhauſted from the tube, the preſſure of the atmoſphere upon the liquor within is diminiſhed; but the preſſure on the outſide liquor is the ſame as before; therefore it follows, that the liquor in the tube muſt be impelled upwards. Inſtead of the lips, an air-pump, by means of a bent tube, may be eaſily applied to exhauſt the air.

Let this experiment be tried with quickſilver, and a glaſs tube above three feet long; and it will be found, that according as the air is exhauſted, the quickſilver riſes within the tube, but when it is arrived to a certain height, viz. about thirty inches above the ſurface of the quickſilver in the baſin, there it ſtops; and although the exhauſtion of the air from within the tube be carried to a great degree by any poſſible means, the quickſilver cannot be made to riſe any higher. This ſhews that the preſſure of a column of the atmoſphere is equivalent to the preſſure of a column of quickſilver about thirty inches high, and of the ſame baſe. Hence it appears, that if the earth, inſtead of its aerial atmoſphere, was ſurrounded by an atmoſphere of quickſilver, only thirty inches high, it would ſuſtain the ſame preſſure it actually does from the real atmoſphere.

If the above-mentioned experiment be tried with water and a very long tube, it will be found, that the water will not riſe higher than about thirty-five feet, viz. fourteen times thirty inches, fourteen times the height at which quickſilver will aſcend, becauſe quickſilver is about fourteen times heavier than water; and if a column of the atmoſphere balances a column of quickſilver thirty inches high, it muſt balance a column of water fourteen times as high, which is equal to thirty-five feet.

From this it appears why, in ſucking water-pumps, the water under the piſton cannot riſe higher than thirty-five feet above the ſurface of the water in the well. Indeed in common pumps the water does not riſe near ſo high, becauſe the piſtons of thoſe inſtruments are not made ſo nice as to exhauſt the air ſo well as an air-pump.

From this principle we deduce an eaſy method of computing the preſſure of the atmoſphere upon the ſurface of any body; for a column of quickſilver about thirty inches high, and one inch in diameter, weighs about 15lb. and a half; and as a column of the atmoſphere balances a column of quickſilver of about thirty inches perpendicular height; therefore we conclude, that the preſſure of the atmoſphere is equal to about 15½lb. per ſquare inch of ſurface: hence, if the ſurface of a given body is equal to four ſquare inches, the atmoſphere preſſes upon it with a weight of 62lb. (i. e. four times 15½lb.)

The abſolute weight of the air is found in the following manner:—A glaſs bottle of known dimenſions is weighed, both when filled with common air, viz. as it is naturally when kept open in the air, and when emptied of air, viz. after that the air has been exhauſted from it by means of a good air-pump; the difference of which weights is the real weight of a quantity of air equal to the capacity of the bottle. Thus it has been found, that a quart meaſure of air, taken near the ſurface of the earth, weighs 16 grains. But a quart meaſure of water weighs about 914 times as much; therefore the ſpecific gravity of air, taken near the ſurface of the earth, is to the ſpecific gravity of water as 1 to 914, nearly.

The great difference to be remarked between the mechanical properties of air, and of water, is, that air is a very elaſtic ſubſtance, whereas water is not elaſtic*, viz. water, and moſt viſible fluids, do not contract into a ſmaller ſpace when they are compreſſed. By means of proper inſtruments,

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* Having remarked, towards the beginning of this book, that water, ſtrictly ſpeaking, is compreſſible; but that its degree of compreſſibility is ſo exceedingly ſmall, that it can be but juſt rendered ſenſible by very nice experiments; we may, ſafely enough for our purpoſe, conſider it as uncompreſſible.

ſtruments, a ſtrong veſſel may be made to hold eight, ten, or many more times as much air as it holds in a natural ſtate. In that caſe, the preſſure of the air within the veſſel, or the air's endeavour to expand, acts againſt its ſides; and if the veſſel is not ſufficiently ſtrong, it may be eaſily broke by that means; for that preſſure is many times greater than the outward preſſure of the atmoſphere. It is very remarkable, that the air, by being kept highly compreſſed for a long time in proper veſſels, loſes nothing of its elaſticity; ſo that whenever the preſſure that confined it into a ſmall ſpace, is removed, it returns again into its natural ſtate of denſity, viz. occupies as much ſpace as it did in the ſame circumſtances, before it was compreſſed.

The air near the ſurface of the earth, ſuſtaining the preſſure of the ſuperincumbent air, is condenſed into a much ſmaller ſpace than it would occupy if that preſſure was removed; but the air higher up, as it ſuſtains leſs preſſure, is leſs condenſed; ſo that the denſity of air is greateſt in the bottoms of pits, wells, or, in ſhort, where it is neareſt to the center of the earth; and it becomes gradually more and more rare, as it is farther from the center of the earth. Accordingly we find, that a bottle filled with air on the top of a high mountain, weighs leſs than when it is filled with air about the middle of the mountain, and ſtill leſs than when it is filled in a place level with the ſea, or lower.

The water near the bottom of a veſſel filled with it, is of the ſame denſity with the water above; hence, if the preſſure of the water near the bottom of the veſſel is aſcertained by means of a bent glaſs tube containing quickſilver, or otherwiſe, and the ſpecific gravity of the matter is known, the depth of the water in the veſſel will thereby be alſo known, without actually meaſuring it: for ſuppoſe that the column of quickſilver raiſed in the tube by the preſſure of the water is 10 inches high; quickſilver is fourteen times as heavy as water; therefore it follows, that the depth of the water in the veſſel is 11 feet, 8 inches, viz. fourteen times 10 inches.

After the ſame manner, if the air was equally denſe, and conſequently equally heavy, at any diſtance from the ſurface of the earth, we could eaſily know the height of the atmoſphere above the earth; for it is known that the preſſure of the atmoſphere balances a column of quickſilver about 30 inches high; it is alſo known, that the ſpecific gravity of air is to the ſpecific gravity of quickſilver as 1 to 12,796 *. In that caſe, therefore, the height of the atmoſphere would be 12,796 times 30 inches, viz. 31,990 feet. But as the denſity of the air decreaſes according to its diſtance from the center of the earth, it follows,

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* It has been mentioned above, that water is 914 times as heavy as air, and that quickſilver is 14 times as heavy as water; therefore quickſilver is 14 times 914 times as heavy as air. Multiply 914 by 14, and the product is 12,796, which number ſhows how many times quickſilver is heavier than air.

lows, that the real height of the atmoſphere muſt be much greater. Were this decreaſe always uniform, and depending only upon the preſſure of the ſuperincumbent air, we might even then aſcertain the height of the atmoſphere; but becauſe air, independent of preſſure, is contracted conſiderably by cold, and alſo expanded by heat, and as various degrees of temperature are obſervable at different diſtances from the ſurface of the earth, we have no certain data from which we may calculate the real height of the atmoſphere.

Mr. COTES, conſidering the condenſation of air as ariſing only from the weight of the ſuperincumbent air, has ſhewn, that the denſity of the air decreaſes as the ſquares of the diſtances from the ſurface of the earth; ſo that the air at 3 miles diſtance is 9 times rarer than that at 1 mile; the air at 10 miles diſtance is 100 times rarer than that at 1 mile, &c.

The principal laws relating to the elaſticity of the atmoſpheric air, are the following: I. Air is condenſed by preſſure, and the ſpace it contracts into is in the inverſe ratio of the preſſure; thus, if one pound weight confines a quantity of air, which in a natural ſtate occupies the ſpace of 12 cubic inches, into a ſpace equal to 6 cubic inches; two pounds weight will reduce it into 3 cubic inches; three pounds weight will reduce it into 2 cubic inches, &c. The experiments hitherto made do not ſhew the ultimate limit of the air's condenſation; for after having been compreſſed as much as the inſtruments made for that purpoſe could ſuffer, it ſtill ſeemed capable of much greater compreſſion, by applying a greater force. Neither preſſure nor cold, or indeed any other means, ever exhibited air in the form of a ſimple ſolid, or of a viſible fluid. II. As air is contracted into a ſmall ſpace by preſſure, ſo it expands into a greater ſpace when the preſſure that confines it is removed. The limit of this expanſion is not known; for the experiments hitherto made do not ſhew that air expanded to a certain degree is not capable of farther expanſion. III. The elaſticity of air does not ſeem to be impaired by long-continued preſſure or rarefaction; ſo that if a given quantity of air is kept for a long time highly compreſſed, or very much rarefied, it will always return into the ſame given quantity, whenever it is put into the ſame circumſtances it was before the compreſſion, or the rarefaction. IV. Independent of preſſure, air is rarefied by heat, and on the contrary, is contracted by cold; although this rarefaction or condenſation of air by heat and cold only, cannot be carried to ſo great a degree as it may by the addition or removal of preſſure. V. The gravity of the atmoſphere varies continually; ſo that if at one time it balances a column of quickſilver of 30 inches perpendicular height, at another time, it balances an higher or ſhorter column of the ſame. The limits of this variation are 28 and 31 inches, in places nearly level with the ſea; ſo that the ſhorteſt column of quickſilver balanced by the atmoſphere is 28, and the higheſt 31 inches. I have heard of the quickſilver ſometimes having been ſeen lower than 28, or higher than 31 inches; but theſe extraordinary caſes, if they are at all true, happen very rarely.

A glaſs tube a little more than 31 inches high, cloſed at one end, accurately filled with quickſilver, and immerſed in a baſin filled with the ſame, has been called a *barometer*, which ſhews the gravity of the atmoſphere at different times; for as the ſurface of the quickſilver in it is never lower than 28, nor higher than 31 inches above the ſurface of the quickſilver in the baſin, a ſcale of 3 inches, uſually divided into tenths, and by means of a nonious into hundreds of an inch, is affixed to the tube from 28 to 31 inches above the ſurface of the quickſilver in the baſin; by which means the height of the quickſilver in the tube, i. e. the gravity of the atmoſphere at different times, may be obſerved to a great exactneſs.

Theſe laws relating to the air's elaſticity will be illuſtrated by the following experiments and explanations.

Take a glaſs tube, not leſs than half an inch in diameter, in the ſhape of A B D E, fig. 12, hermetically cloſed at A, and holding it with the curvature downwards, pour a ſmall quantity of quickſilver in it, ſo as barely to fill the horizontal part D E, in order to confine the air in the cavity A D of the tube; and as the ſurface of the quickſilver near E is on the ſame level with that at D, we may conclude, that the air in A D is not preſſed by any other weight beſides that of the atmoſphere, viz. the barometrical height of the quickſilver at the time of making the experiment. Now let more quickſilver be poured into the leg B E, which will compreſs the air in A D, and will confine it into a ſmaller ſpace A C. The whole weight, therefore, that condenſes the air into the ſpace A C, is the column of quickſilver in the leg B E (reckoning it from the ſurface F, to G, the level of the ſurface C of the quickſilver in the other leg) more the barometrical height, viz. the natural preſſure of the atmoſphere. Thus, by pouring more quickſilver into the leg B E, the weight, that preſſes upon the air in A C, may be increaſed at pleaſure; but it will be conſtantly found, that the ſpace A C, into which the air is condenſed, is to the ſpace A D, occupied by the ſame quantity of air in a natural ſtate, as the barometrical height of the quickſilver (viz. as the force which compreſſed the air whilſt it was contained in the ſpace A D) to the barometrical height of the quickſilver, and the height of the column F G (viz. to the weight which compreſſes the ſame quantity of air, whilſt it is contained in the ſpace A C); which evidently ſhews, that the ſpace which air poſſeſſes is inverſely as the force that confines it.

In this manner air may be compreſſed as much as the glaſs tube will bear.

The leg A D of the tube in this experiment is ſup-

poſed

poſed to be perfectly cylindrical; otherwiſe the ſpaces occupied by the air cannot be meaſured by the length of the tube.

It is almoſt needleſs to mention, that air compreſſed becomes more denſe, heavier, &c.; it being obvious, that a given quantity of air, confined in half the ſpace it naturally occupies, muſt become twice as denſe, muſt be twice as heavy as it was before, muſt offer a greater reſiſtance to the motion of bodies in it, &c.

The expanſion of air, when the preſſure of the atmoſphere is removed, is ſhewn by all the experiments commonly made with the air-pump, the conſtruction and uſe of which inſtrument is deſcribed in a great many books. By thoſe experiments it appears, that after taking out of the cavity of a given receiver the greateſt part of the air contained, the ſmall portion of it, that laſtly remains, is equally expanded throughout the cavity of the receiver, without being more denſe at the bottom than at the top of it.

In order to ſhew that heat rarefies the air, let the tube B E D C, fig. 12, uſed in the preceding experiment, when the air confined in it by quickſilver occupies the ſpace AC, be brought near the fire, and it will immediately appear that the air in A C is rarefied by the heat, becauſe the ſurface C of the quickſilver is gradually lowered. But if, inſtead of bringing the tube near the fire, it be carried into a cold place, or the part A D be put in ſnow, the confined air will be immediately contracted into a ſpace leſs than A C, and the quickſilver will accordingly riſe above its former place C.

Take a common bladder, and by blowing throw ſome air in it, ſo as not to fill it quite; but let it remain rather flaccid. Then tie the neck of it, and bring it near the fire; by which means the air contained in the bladder will be expanded, as will appear by the diſtenſion of the bladder. If the heat is ſuch as to rarefy the air within the bladder more than the bladder can bear, the elaſticity of the expanded air will burſt it, with great violence and noiſe.

This admirable property of the air, viz. of being eaſily expanded by heat, and contracted by cold, is the principal if not the ſole cauſe of winds; it keeps the air about us continually agitated, by which means the putrid and offenſive effluvia, ariſing from corruption of matters, exhalations, reſpiration, fermentation, &c. are providentially ſwept and removed from us.—Air heated in one part of the world becomes lighter, conſequently aſcends, and other heavier and colder air ſupplies its place. If the air in one place becomes colder, by the ſetting of the ſun, or other cauſes, it contracts into a ſmaller ſpace, and the hotter air from the circumjacent places runs towards that part. Thus the winds are formed, which are weak, ſtrong, periodical, changeable, &c. according to the duration, intenſity, and direction of thoſe cauſes, which rarefy or condenſe the air by heat and cold.

To render the circulation of air ſenſible, let the air of a room be heated by a ſtrong fire, whilſt the air of a contiguous room is cold; then let the door between theſe two rooms be opened, in which caſe the hot air of one room, being lighter, will paſs through the upper part of the opening of the door into the cold room; and, on the contrary, the cold air of the other room, being heavier, will paſs into the former room through the lower part of the opening; accordingly it will be found, that applying a lighted candle at the top, in the middle, and at the lower part of the opening between the two rooms, a ſtrong current of air will appear to paſs from the hot into the cold room near the top; a contrary current of air will appear to paſs from the latter into the former room near the lower part of the ſaid opening; whilſt in the middle there is little or no motion at all; as may be clearly perceived by the direction of the flame of the candle.

It is for the ſame reaſon, that when the fire is lighted in a chimney, a ſtrong current of air is occaſioned to enter the room, which may be felt by applying the hand near the key-hole, or other ſuch ſmall openings, if the doors and windows are ſhut; for the air over the fire being heated becomes lighter, and aſcends into the chimney, conſequently other colder air muſt ſupply its place, which forces its way through all the ſmall openings it can find.

Were a room with a fire in it to be perfectly cloſed, excepting the chimney, the air in it would ſoon become unwholeſome for reſpiration, and the fire would be ſoon extinguiſhed, beſides other inconveniences. Hence it appears, that thoſe perſons miſtake, who expect to keep the air of a room ſweet and wholeſome, eſpecially for convaleſcents, by accurately ſtopping all the ſmalleſt openings that admit freſh air.—When the current of air that enters into a room is on ſome ſide of it where it falls immediately upon the perſons who ſit in the room, then it may be offenſive, eſpecially to delicate conſtitutions. In that caſe, ſuch opening ſhould be cloſed; but at the ſame time another opening ſhould be made for admitting freſh air, in another more convenient part; for a circulation of air, eſpecially in rooms where a fire is kept, is not only ſalutary and uſeful, but is abſolutely neceſſary.

In an ingenious publication, entitled *A Practical Treatiſe on Chimneys*, there are the following remarks relating to the propereſt method of admitting air into a room, and of expelling the contaminated air. The author, directing to make a vent-hole near the top of the room, in order to expel the heated and contaminated air, " This, *ſays he*, " might be done by means of a ſmall tube opening into " the room, either in or near the ceiling; which might " either be carried to the top of the building, or be made " to communicate with the external air by a ſmall per-" foration through the wall at the roof of the room, by

" means of either of which a proper circulation would be
" eſtabliſhed, and the foul air be carried off.

" For the fire would no ſooner have warmed any particles of air within the room, than theſe would be greatly expanded, and riſe immediately upwards, ſo as to fill the higher parts of the room with rarefied air;—and as other particles would be ſucceſſively heated and rarefied in their turn, by their expanſive force, they would preſs upon the ſides of the apartment in every place, ſo as to force the lighteſt particles through the opening left for that purpoſe in the top of the room; by which means the fouleſt air would be gradually drawn off, without deſcending again into the lower regions, to the annoyance of the company."

But in order to admit freſh air into the room, " Let, *ſays he*, another opening be made in the ceiling of the room, having a communication with a ſmall pipe that ſhould lead from thence either to the outſide of the wall, or to any other part of the building that might be judged more convenient, where it ſhould be bent, and conducted downwards, till it reached the ground; where it ſhould be left open, to communicate with the external air.—In this ſituation the cool external air would be forced in at the lower opening of the tube *,

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* " Such readers as have been little accuſtomed to ſpeculations of this ſort, will be at a loſs to comprehend in what manner two holes, both of them in the roof of the room, and communicating with the air, without any valve, or

“ and made to aſcend into the apartment in proportion to the quantity that eſcaped towards the higher regions by means of the ventilator.—And as that weighty air would no ſooner enter the room, than it would tend towards the floor by its own natural gravity, it would gradually mix with the heated air in it's deſcent—become, in ſome meaſure, warmed by that means, and equally diſperſed through the room, ſo as ſlowly and imperceptily to reach the candles and the company in the room, and ſupply them with a ſufficient quantity of freſh and wholeſome air, without the inconveniences to which the company are ſubjected by the uſual way of admitting freſh air. For if it enters near the floor of the apartment, it is hurried along in a rapid undivided ſtream towards the fire-place, and ſtriking upon the legs and inferior parts of the body, affects

“ or other contrivance, for opening or cloſing of themſelves, ſhould yet anſwer the two very oppoſite purpoſes; one of conſtantly bringing cool air into the room, without emitting any warm air—and the other, of as conſtantly emitting warm, and admitting no cool air. They will pleaſe to advert, that the one of theſe tubes communicates with the atmoſphere *at the bottom* of the houſe, and the other towards *the top*:—The opening of the one is beneath the level of the room, that of the other above it. Now as the air is more denſe at the ſurface of the ground than at any height above it, the warm rarefied air will naturally iſſue at that opening where it meets with leaſt reſiſtance, which muſt invariably be through that which opens to the external air at the greateſt height; and as the cool air will naturally be preſſed into the room by that opening where the air is moſt weighty; this muſt invariably be by that which is neareſt the ſurface of the earth.”

“ them with a ſtrong ſenſation of cold. To overcome
“ the effects of this, large fires muſt be kept; by which
“ other parts of the body are warmed to an extraordinary
“ degree, which is productive of moſt of thoſe diſorders
“ that are pernicious to the young, and often prove fatal
“ to the old, during the winter-ſeaſon, in theſe cold regions.

“ Thus might our apartments be kept conſtantly, and
“ moderately, and equably warm, at a moderate expence,
“ without endangering our health on the one hand, by
“ reſpiring a confined, ſtagnant, and putrid air—or,
“ on the other hand, by ſubjecting ourſelves to ſuch
“ danger of catching colds, conſumptions, and rheumatic
“ complaints, by being expoſed to ſuch exceedingly unequal
“ degrees of heat and cold, as are unavoidable
“ where our apartments are ſo open as to admit a ready
“ paſſage to the external air during the winter ſeaſon.

“ The reader will eaſily perceive, that all that has been
“ here ſaid has a reference only to thoſe apartments in
“ cold climates, and rigorous weather, where fire to warm
“ them becomes neceſſary.—In warmer regions, or during
“ the ſummer-ſeaſon, there can be no objection to
“ the wheel-ventilator in the window.—It is a ſimple
“ contrivance, and a ſafe and effectual mean of preſerving
“ the air in our apartments ſweet and wholeſome at
“ that ſeaſon.”

It is a vulgar error among many people, to believe that fire purifies the contaminated air, by deſtroying the noxious particles mixed with it; and for this reaſon they think, that the fire kept in a room where the air is tainted, purifies the room, by rendering the air in it again fit for reſpiration. Indeed, a fire kept in a room or apartment where the air is tainted, as is the caſe with hoſpitals, gaols, and the like, does certainly purify the apartment, and the practice is very uſeful; but this effect is only becauſe the fire promotes the circulation of the air, and dries the dampneſs of rooms, furniture, &c.; ſo that it is not the infected air that is purified, but is new, freſh, and wholeſome air, that by the action of the fire has taken the place of the infected air; which infected air, being rarefied by the heat, has been expelled from the apartment. Fire and combuſtion in general, as will be ſhewn in the ſequel, is ſo far from purifying contaminated air, that it actually contaminates a prodigious quantity of it in a ſhort time; ſo that not only a common fire, but even a lighted candle, when kept in a well-cloſed room, wherein the external air has not a free acceſs, inſtead of purifying, renders the air of that room noxious.

It now remains to mention ſome intereſting particulars relating to the change of the atmoſphere's preſſure, viz. to the different heights of the quickſilver in the barometer at different times. The obſervations and experiments hitherto made in regard to this difficult and intereſting point of natural philoſophy, do only point out ſome phænomena concomitant to thoſe changes, but by no means diſcover their cauſe. That the reader may be left at liberty to inveſtigate this cauſe by himſelf, I ſhall add the principal general obſervations made with the barometer; after which I ſhall barely mention a few hints, which may aſſiſt that inveſtigation.

It was mentioned above, that the motion of the quickſilver in the barometer is only between 28 and 31 inches; the mean of which is 29½ inches: ſo that by the barometer being low, we mean, that the quickſilver in it ſtands at ſome point between 28 and 29½ inches; and by the barometer being high, that the quickſilver ſtands above 29½ inches.

I. In ſerene, ſettled, good weather, and eſpecially in calm froſty weather, the barometer has been obſerved to ſtand generally high. II. On the contrary, in calm weather, when the atmoſphere is inclined to rain, the barometer is generally low. III. Upon very violent winds, although it does not rain, the barometer is generally lower than at any other time; but it ſeems to have ſome reference to the point of the compaſs, upon which the wind actually blows; for at particular places the quickſilver ſinks very low when the wind blows hard from one quarter only, but not when it blows from other quarters. IV. After violent ſtorms of wind, when the barometer has been low, it commonly riſes very faſt. V. Laſtly, theſe variations are much more ſenſible in northerly places than in thoſe that are more ſoutherly. In the Weſt Indies, and generally in all places within the tropics, the barometrical variation is hardly ſenſible. Indeed, at the time of hurricanes, the quickſilver ſinks very low; but theſe extraordinary ſtorms happen perhaps only once in two or three years, and are of ſhort duration.

As the barometer, by its being low at the approach of ſtorms and rainy weather, and on the contrary, by its being high in good weather, in a great meaſure predicts the ſtate of the weather; it has been called the *weather-glaſs*, and the words *ſtormy weather*, *fair*, *ſettled*, *variable*, &c. are uſually written, upon the ſcales of common barometers, againſt thoſe heights at which the quickſilver more uſually, though not invariably, ſtands in thoſe particular ſtates of the weather.

The variations of the preſſure of the atmoſphere are not only perceived by means of the barometer, but they do ſenſibly affect various animals, eſpecially of the human ſpecies. Thus, in ſerene, clear weather, when the atmoſphere is more heavy, we are generally more chearful and vigorous; the greater weight of the atmoſphere bracing our fibres much better: but in foul and rainy weather, when the barometer is low, we are generally languid and dull; the air incloſed within the body, being counterbalanced by a leſs external weight, diſtends the body, occaſions flatulencies, pains, uneaſineſs, &c. Theſe effects are more ſenſibly felt by old people, and convaleſcents, whoſe conſtitution, being enfeebled, becomes ſenſible of any the leaſt variation. Hence it is, that ſome people can predict the changes of the weather almoſt as well as a barometer. It muſt however be acknowledged, that the uneaſineſs, and other ſymptoms, obſerved upon our bodies in bad weather, are in great meaſure alſo owing to the dampneſs of the air at that time.

Dr. Halley ſuppoſes, that the principal cauſe of the variable gravity of the atmoſphere is from the changeability of winds; ſo that within the tropics, the wind being generally periodical, and in one direction, the barometer ſhews very little variation; but in places more northerly, as is the caſe here in England, the wind changes very often, accordingly the variation of the barometer is more ſenſible; but yet this variation of the wind, and of the barometer, ſeem not to coincide together ſo well as to put the aſſertion out of doubt.

When the barometer is low, it is ſuppoſed that it moſtly rains; becauſe the atmoſphere, being lighter than at other times, is not capable to buoy the aqueous particles ſo well as it does when it is heavier, in which ſtate it is moſtly ſerene weather.—This conjecture is ingenious and natural; but ſuppoſe that in ſerene weather a ſtorm approaches, the quickſilver in the barometer ſinks;—the ſtorm paſſes beyond the horizon, and the quickſilver again riſes to its former degree. Now in this caſe, it is difficult to ſay, whether the ſtorm happened in conſequence of the air becoming ſuddenly lighter, or the air is become lighter in conſequence of the ſtormy clouds approaching. Perhaps electricity has ſome connection with the change of gravity of the atmoſphere. In ſerene clear weather, eſpecially when it is cold and froſty, the electricity of the atmoſphere is very ſtrong; but in rainy, warm, and cloſe weather the atmoſpherical electricity is ſcarcely ſenſible. Some perſons imagine that there is a tide in the atmoſphere, analogous to the tide of the ſea, as they (viz. the tide of the ſea and variation of the atmoſphere's preſſure) coincide ſo far as to be both leſs ſenſible in places neareſt to the equator, than in other parts more remote from it. This ſuppoſition is not void of probability; but the variation of the barometer does by no means ſeem to coincide with the periodical motion of the moon or ſun, as the ſea-tide does. Perhaps the different gravity of the atmoſphere depends upon all theſe cauſes together; ſo that its variation ſhould be deduced from an eſtimate of the action of the winds, of the action of electricity, and of the period of the ſuppoſed tide, beſides the difference which may alſo ariſe from heat and cold.

Omitting to deſcribe the conſtruction of particular barometers, and alſo of their uſe for meaſuring the heights of mountains, &c. as things foreign to our purpoſe; I ſhall conclude this chapter with a few experiments, ſhewing ſome uſes of the preſſure of the atmoſphere in our experimental inquiry on the nature and properties of elaſtic fluids.

It was mentioned above, that if one end of an open glaſs tube be immerſed in quickſilver, and, by means of an air-pump applied to the other aperture of the tube, the air be exhauſted from it, the quickſilver will riſe in the tube as far as about 30 inches perpendicular height; but this experiment may be made more eaſily without the air-pump, in the following manner:—Take a glaſs tube, not leſs than three feet in length, and cloſed at one end. Fill it entirely with quickſilver; then put your finger upon the open end of it; turn that end downwards, and immerſe it, together with the finger, in a ſmall baſin, alſo full of quickſilver, ſo that the end of the tube may be a ſhort way below the ſurface of the quickſilver in the baſin. This done, ſlip your finger off, and if you hold the tube perpendicular, viz. with the cloſed end upwards, and the open end in the baſin, the quickſilver will remain ſuſpended in it between 28 and 31 inches perpendicular height above its ſurface in the baſin. The remaining part of the tube, above the quickſilver, is void of air, and much more ſo than if it were exhauſted with the beſt air-pump; for the air-pump, by the nature of its conſtruction, muſt always leave ſome ſmall portion of air in the receiver that is exhauſted with it, the denſity of which remnant of air is always equal to the denſity of that portion which the air-pump exhauſted by the laſt ſtroke. But in the above-mentioned experiment, generally known under the name of the *Torricellian experiment* *, the vacuum is much more perfect; eſpecially if the quickſilver be boiled in the tube, previous to inverting it (as is practiſed in the conſtruction of the beſt barometers) in order to expel thoſe ſmall portions of air, which, in ſpite of every precaution, do always remain between the ſurface of the glaſs and the quickſilver. Indeed, this Torricellian vacuum is the moſt perfect vacuum that human art can make at preſent. It is eaſily made, and may be applied to various philoſophical purpoſes.

If the tube, after filling it, and inverting it in the baſin, be lifted up above the ſurface of the quickſilver in the baſin, the air will ſoon introduce itſelf into the tube, and aſcending on one ſide of it, between the quickſilver and the glaſs, will cauſe the quickſilver to deſcend, and conſequently to drop out of the tube.

It is plain, that if the above-mentioned experiment be tried with a tube, a vial, or any receiver ſhorter than 28 inches, on inverting it, the whole cavity of the receiver, or tube, &c. will remain filled with quickſilver. The ſame experiment may be tried with water inſtead of quickſilver; but in this caſe, in order to make a vacuum, the tube ſhould be above 35 feet long; for every receiver, which does not meaſure ſo much, on being inverted, will remain intirely filled with water.

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* *Torricelli* is the name of a Philoſopher, who diſtinguiſhed himſelf for his aſſiduous inveſtigation of the nature and laws of the air's preſſure.

By this means we may eaſily confine a quantity of common air, or other elaſtic fluid, and alſo change it from one receiver into another without letting it mix with the atmoſphere.—Take any common glaſs-receiver, a glaſs-vial, or any veſſel of the like ſort, fill it with water, then put your finger, or the open hand, upon the mouth of it, ſo as to let no water drop out, and invert it in a baſin of water, ſo as the mouth of the veſſel may be a little way below the ſurface of the water in the baſin; then ſlip off the hand, and the glaſs will remain quite filled with water, although it is all out of the water in the baſin, excepting its mouth. This glaſs-receiver, ſo filled, is repreſented fig. 13. If it be aſked, what power keeps the water in the glaſs ſo elevated above the water in the baſin A B? we anſwer, that it is the weight of the atmoſphere, which preſſes upon the ſurface of the water in the baſin. This may be eaſily proved, by introducing the apparatus A B C, as it ſtands under the receiver of an air-pump, and exhauſting the air from it; for then the atmoſpherical preſſure upon the ſurface of the water in A B being removed, the water will deſcend from within the glaſs C D. Now ſuppoſe that ſome air is required to be kept for ſome time in this glaſs-receiver;—take a ſmall veſſel, as a tea-cup, plunge it in the water of the baſin A B, but with the mouth downwards, in which caſe the air will not eſcape from it; then lift the glaſs C D from the bottom of the baſin, but not ſo high as to come out of the water; bring the cup under it, and there turn the cup with the mouth upwards, in which caſe the air will eſcape out of it, and will aſcend to the upper part of the glaſs C D, where it may be kept for any length of time, it being confined by the water. The cup is not required to be kept in the baſin any longer, after that has been emptied of its air. If the glaſs C D, when the water is firſt poured in it, be not quite filled, then be ſtopped with the hand, and be immerſed, &c. or an empty receiver be ſimply immerſed with its mouth in water, a quantity of common air will alſo be confined in that receiver by the water in the baſin; but the method above deſcribed is not only more preciſe, but is applicable to every other elaſtic fluid, and is of general uſe in performing experiments on them; I think, therefore, it will not be improper to illuſtrate it by the figs. 14 and 15, in order that the reader may make himſelf maſter of it, previous to his proceeding farther in the performance of more difficult experiments. Fig. 14, ſhews the receiver filled with, and immerſed in water, but kept ſo as not to touch the bottom of the baſin or tub, together, and the inverted cup plunged in the water; where, it may be obſerved, that although the cup, which is delineated as if it were tranſparent, is filled with air, yet the water preſſing upon that air condenſes it a little, ſo that the water in fact aſcends a little way within the cup. Fig. 15, ſhews the air which comes out of the cup, when this is inverted, and being lighter, aſcends through the water in the form of bubbles, to occupy the upper part of the receiver; whilſt at the ſame time the cup is filled with water.

It is almoſt needleſs to mention, that the ſame experiments may be performed with quickſilver inſtead of water; but whenever quickſilver is uſed in ſuch experiments, care ſhould be taken to uſe very ſtrong receivers, ſtrong cups, &c. and alſo to manage them very dextrouſly, otherwiſe the great weight of the quickſilver will endanger their breaking.

CHAP. III.

Containing ſome effects of condenſed and rarefied air, and a ſummary view of the different ſtates of the atmoſpherical air in various parts of the world.

SOON after the diſcovery of the air-pump, and of the condenſing engine, philoſophers, among whom the famous Boyle particularly diſtinguiſhed himſelf, notwithſtanding the many imperfections of thoſe firſt inſtruments, began to examine the effects of rarefied and condenſed air upon various bodies, eſpecially animals and fluids; thoſe effects being not only remarkable in themſelves, but explaining the phenomena of various natural ſtates of the atmoſphere in divers parts of the world. Upon mountains, for inſtance, the air is much more rare than in places that are level with the ſea; accordingly it has been obſerved, that upon very high mountains, thick ſmoke, inſtead of aſcending, deſcends till it arrives to that region of the atmoſphere where the air is denſe enough to keep it afloat. For the ſame reaſon, ſmoke alſo deſcends into the half-exhauſted receiver of an air-pump. Perſons who travel over very high mountains, find a very ſenſible uneaſineſs in breathing, ariſing from the rarity and levity of the atmoſphere at thoſe elevated regions; ſometimes, eſpecially when they firſt arrive at the top of the mountain, the diſtenſion of the internal air, not ſufficiently balanced by the external preſſure of the atmoſphere, occaſions them to vomit, often even blood; but after ſome time they become more uſed to that temperature; the air within the body, by being partly emitted, gradually becomes nearly of the ſame denſity with the external air, and the diſagreeable ſymptoms are gradually mitigated to a certain degree. Now theſe effects of rarefied air are exactly imitated with an air-pump. An animal, as a mouſe, a bird, a kitten, or the like, being put into the receiver of an air-pump, ſhews his reſpiration to be affected, when not more than a fourth or fifth part of the air contained in the receiver has been exhauſted. By working the pump

farther,

farther, the animal begins to vomit, becomes inflated, loſes its ſtrength, falls gaping, and laſtly dies.

In order to proceed regularly in the account of the principal effects of rarefied and condenſed air, we ſhall begin from the effects produced upon inanimate bodies.

When liquors of various ſorts, as for inſtance water, is put into any cup under the receiver of an air-pump, on exhauſting the air, the liquor ſhews a kind of ebullition, many bubbles riſing from within it, which break near the ſurface; but this ebullition is not attended with any ſenſible heat, the bubbles being not ſteam occaſioned by heat, but being only formed by ſmall portions of air, which collect together when the uſual preſſure of the atmoſphere is removed, and expanding into large bubbles, force their way through the water. Thus we learn that water, ſpirit of wine, animal fluids, and moſt other fluids, eſpecially fermented liquors, contain a conſiderable quantity of air concealed amongſt their particles, ſo as to be inviſible to us whilſt thus mixed. After that ſome elaſtic fluid has been exhauſted from a liquor, if the air be again let into the receiver of the air-pump, and then be exhauſted anew, without altering the apparatus, the liquor will not ſhew any ebullition, or a ſcarcely ſenſible one, becauſe, having loſt all the air it contained by the firſt exhauſtion, the cauſe which occaſioned that ebullition is no longer exiſting; and, in order to let the liquor imbibe again as much air as it contained before the exhauſtion, it muſt be expoſed to air, and muſt be agitated for ſome time in it. The quantity of common air that water is capable of abſorbing, is different in different temperatures, and under various preſſures of the atmoſphere; but in a temperate degree of heat, and when the barometer is about 29½ inches, it may be eſtimated to be about one fortieth of the bulk of the water. Dr. HALES ſays, to be one fifty-fourth part, and the Abbé NOLLET, one thirtieth of the bulk of the water. Water, by being thus mixed with air, is ſaid not to acquire any addition of bulk; but MUSCHENBROEK obſerves, that air abſorbed by water increaſes ſo very little the bulk of the water, that it is ſcarcely perceivable by very nice experiments. It is not to be wondered, that a mixture of water and air ſhould occupy leſs ſpace than the ſum of both their bulks, ſince air, which is ſo rare a fluid, may be ſuppoſed to fill thoſe interſtices, which, we may reaſonably ſuppoſe, do always exiſt between the particles of water. Otherwiſe, we cannot eaſily form any idea of a fluid. But this phenomenon is very common in chymical mixtures. The reader may remember what was ſaid concerning the ſpirit of wine in the preceding pages.

In the third part of this work will be mentioned the quantity of air, or other elaſtic fluid, uſually contained in ſeveral mineral waters, and other liquors, together with the various methods practiſed to extract thoſe elaſtic fluids; but in general it is impoſſible to aſſert with preciſion the quantity and quality of elaſtic fluid that is contained in ſpring, rain, river, or ſtagnating water, and in divers other liquors; that quantity and quality varying in almoſt every ſpecimen, according to many different circumſtances.

It was obſerved in the preceding pages, that water boils in a degree of heat equal to the 212° of FARENHEIT's thermometer; but this is only true when the barometer ſtands at 30 inches; for under a greater or leſs preſſure of the atmoſphere, the degree of heat at which water boils is ſomewhat different. This experiment cannot be tried under the exhauſted receiver of the air-pump, becauſe the ſteam riſing from the water, whilſt yet hot, is an elaſtic fluid, which filling the receiver, fruſtrates the intention of the experiment; but it has been tried upon mountains, in pits, and alſo upon ground nearly level with the ſea, at different times, when the quickſilver in the barometer was differently high.

From various obſervations of this ſort, made by two ingenious members of the Royal Society, Mr. DE LUC, and *Sir* GEORGE SHUCKBURG, the following table has been deduced; which, as far as thoſe obſervations reach, ſhews the degree of heat of boiling water under different preſſures of the atmoſphere.

TABLE.

Height of the barometer.	Heat of boiling water, according to	
	Mr. De Luc.	*Sir* G. Shuckburg
26,	205,17	204,91
26,5	206,07	205,82
27,	206,96	216,73
27,5	207,84	207,63
28,	208,69	208,25
28,5	209,55	209,41
29,	210,38	210,28
29,5	210,2	211,15
30,	212,	212,
30,5	212,79	212,85
31,	213,57	213,69

The degrees, and decimal parts of a degree, expreſſed in the ſecond and third columns of the table, are according to FARENHEIT's thermometer.

From theſe obſervations it appears, that when good thermometers are graduated, the height of the barometer at the time of fixing the boiling-water point (which is generally done by immerſing the thermometer in boiling water) ſhould be marked on them. The degree of temperature at which water freezes, ſeems to be always the ſame, under different degrees of gravity of the atmoſphere. A common FARENHEIT's thermometer being immerſed in melting ſnow, upon a mountain where the barometer ſtood at about 24 inches, the quickſilver in it fell preciſely to 32°, as it uſed to do in places level with the ſea *.

When the preſſure of the atmoſphere is removed from divers bodies, not only fluids, but alſo conſiſtent bodies, a quantity of common air, or other elaſtic fluid, is diſengaged from them; thus various fluids, the fleſh of animals, eggs, the ſtocks and leaves of plants, &c. when put under the receiver of the air-pump, yield a conſiderable quantity of elaſtic fluid, which is evident from the deſcending of the mercury in the mercurial gage of the air-pump when the exhauſtion is intermitted. It is alſo made to appear very clearly by putting the ſaid bodies into a glaſs full of water, and introduced under the receiver of the air-pump; for in this caſe, on exhauſting the air out of the receiver, many little bubbles of air will appear to come out of the pores of thoſe bodies, and gradually expanding themſelves, force their way to the ſurface of the water, where they break. The water to be uſed in this experiment ſhould be previouſly deprived of its air, by exhauſting it with the air-pump, or by boiling, which anſwers equally well.

Thus we ſee that air, or, in general, an elaſtic fluid, is combined, and forms part of all ſucculent animal and vegetable ſubſtances, and may be extracted from them by merely removing the preſſure of the atmoſphere; but it

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* See the Phil. Tranſ. Vol. LXIX, page 365.

will appear in the ſequel, that from almoſt all ſorts of bodies, even from very hard ſubſtances, an elaſtic fluid of ſome ſort or other may be obtained, by other means different from the mere removal of the atmoſphere's preſſure. What may be the uſe of combining thoſe elaſtic fluids with almoſt every ſort of bodies, and in what ſtate they may exiſt in thoſe combinations, are matters that deſerve much farther experimental inveſtigation than has been hitherto employed about them. It is certainly wonderful to conſider, that an elaſtic fluid is contained in a given body; which body, inſtead of being thereby inflated, and ready to be reduced into duſt, appears ſhriveled and conſiſtent; and yet the elaſtic fluid, when ſeparated, will be found to occupy a ſpace many times larger than the body from which it was extracted *, and the ſaid body, by the loſs of the elaſtic fluid, inſtead of acquiring firmneſs, becomes leſs conſiſtent: hence it appears, that thoſe elaſtic fluids are rather the bonds deſtined by nature to keep together the particles of bodies.

We ſhall conſider thoſe intereſting particulars in more proper places of this work; for the preſent, it is enough to know, that, by various means, elaſtic fluids of different natures are combined with, and may be extracted from,

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* When a quantity of an elaſtic fluid is ſaid to occupy ſuch or ſuch other ſpace, it is underſtood, that it is acted on only by the mean preſſure of the atmoſphere, viz. when the barometer ſtands about $29\frac{1}{2}$ inches, unleſs the contrary is expreſsly mentioned.

moſt natural and artificial bodies, even the hardeſt metals.

It muſt be obſerved, in regard to the production of elaſtic fluids, occaſioned only by removing the preſſure of the atmoſphere, and independent of fermentation and other means, that the elaſtic fluid thus obtained is, in general, much leſs in bulk than the body from which it has been extracted. Perhaps, in general, only this quantity of elaſtic fluid exiſts amongſt the particles of thoſe bodies that yield it, in its natural form, only ſeparated into ſmall portions; whereas the other quantity of elaſtic fluid, otherwiſe obtained, which moſtly exceeds the bulk of the bodies from which it is extracted, when combined with them, probably does not exiſt as if it were compreſſed, but under a ſolid or congealed form. Sir ISAAC NEWTON, conſidering the elaſtic power of air, and the nature of its formation, ſays, that as bodies of every ſort are endowed with an attractive and a repelling power; and as both thoſe powers are ſtronger in bodies, the more ſolid, denſer, and more compact they are; it follows, that when the attractive force is ſurmounted by heat, or any other powerful agent, and the particles of bodies are removed farther than their ſphere of attraction, the repelling power commencing there, occaſions them to repel each other with a force, which is ſo much the ſtronger as they more forcibly cohered together; and thus it ſeems that permanent elaſtic fluids are formed.

As the removal of the atmoſphere's preſſure ſets free ſome elaſtic fluids contained in bodies, ſo, on the contrary, an increaſed preſſure retards the production of elaſtic fluids from thoſe bodies, which yield it naturally under the uſual preſſure of the atmoſphere. Thus, fermenting liquors yield a conſiderable quantity of elaſtic fluid under the uſual gravity of the atmoſphere; but in condenſed air, that production is retarded. Fruits included in a receiver wherein the air is much condenſed, do not yield as much air as they are wont to do in a leſs denſe medium.

It has been aſſerted, that compreſſed air does, in ſome meaſure, retard putrefaction and moulding; but this is not a conſtant effect, that takes place with all ſorts of bodies, nor that I know has been lately tried with a great variety of ſubſtances. If we conſider that condenſed air hinders the free eſcape of elaſtic fluids from bodies, and alſo, that in putrefactions there is generally a diſcharge of elaſtic fluid, it ſeems natural to believe, that condenſed air does really retard putrefaction.—It is ſomewhat ſingular, that modern philoſophers, who have advanced the ſubject of elaſtic fluids to a ſurpriſing degree, ſhould have rather neglected to examine thoſe effects of condenſed and rarefied air, and ſhould have employed their talents almoſt wholly about the diſcovery of new elaſtic fluids, and of their properties; whereas the philoſophers of the laſt age, although not ignorant of the exiſtence of elaſtic fluids different from common air, yet moſtly examined the effects of common air in different degrees of denſity. But it ſeems, that philoſophical purſuits, like other worldly affairs, have each their proper period and ſeaſon.

The preſence of air is neceſſary to cryſtallization; ſo that, in general, a ſaline ſolution will not cryſtallize under the exhauſted receiver of an air-pump. But the ſolution of metals in different menſtruums ſeems not to be affected by the preſence or abſence of air, excepting when the air is ſo condenſed in the receiver, as in great meaſure to hinder the production of elaſtic fluid, which is commonly generated by thoſe ſolutions.

It is almoſt ſuperfluous to mention, that there is no ſound where there is no air; it being well known, that ſounds conſiſt in a particular vibratory motion of the air, communicated to it by the ſounding body, and conſequently cannot exiſt without air. It is commonly uſed by thoſe who ſhew experiments with the air-pump, to put a bell upon a proper frame under the receiver of the air-pump; which bell, by ſhaking the pump, or by ſome mechaniſm, is ſtruck under the receiver; and then, gradually exhauſting the receiver, it is ſhewn, that, according as the air is rarefied, the ſound is diminiſhed, and at laſt becomes unaudible.

The preſence of good air, as we have often obſerved, is abſolutely neceſſary for combuſtion; ſo that if a candle is put under a cloſe receiver, it will be extinguiſhed in a ſhorter or longer time, according to the quantity of air contained in the receiver, and the ſize of the candle; from which it naturally follows, that a candle will burn for a ſhorter time in air that is a little rarefied, and that it will not burn at all in vacuo.

When experiments, relative to fire and combuſtion, are to be made with the air-pump, in order to heat ſome ſubſtances in vacuo, the beſt method uſed, is that of throwing the focus of a burning-glaſs upon thoſe ſubſtances; which focus will not be much hindered by the ſubſtance of the glaſs-receiver. For this purpoſe, burning-glaſſes of various ſizes ſhould be had at hand; for ſometimes the ſun does not ſhine ſo bright as at other times; or a ſtrong heat is required, and in that caſe a larger burning-glaſs is required than would be ſufficient at other times. However, one large concave mirror, or rather a good large lens, may be ſufficient; for when a ſmall degree of heat is required, part of the lens may be covered, and thus a large burning-glaſs may ſerve inſtead of a ſmall one, only it is not ſo manageable; whereas a ſmall glaſs cannot ſupply the place of a large one.

When bodies are put in condenſed air, and inflamed, they conſume faſter than in the ſame bulk of natural uncompreſſed air *; the quantity of matter conſumed in a given time ſeeming nearly to anſwer to the quantity of compreſſed

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* By uncompreſſed air, here, it is meant, that the air is not compreſſed by any other means beſides the uſual preſſure of the atmoſphere, viz. as it exiſts near the ſurface of the earth.

air. But in performing ſome experiments of this ſort, care ſhould be had to uſe very ſtrong veſſels, and a ſmall portion of the combuſtible materials; for an elaſtic fluid is detached from a great many burning bodies; which fluid, added to the condenſed air, which is rendered ſtill more elaſtic by the heat of the burning body, exerts a vaſt force againſt the ſides of the veſſel that confine it, and endangers their breaking with great violence.

In the exhauſted receiver of an air-pump, i. e. in vacuo, heat may be communicated and generated very eaſily; but combuſtion cannot take place. The great promoter of experimental philoſophy, Mr. Boyle, to whom the philoſophical world is much indebted for his numerous experiments and diſcoveries relating to air, in order to obſerve whether attrition could produce heat in vacuo as well as in the open air, contrived an apparatus, by which two pieces of braſs could be ground againſt each other under the exhauſted receiver of the air-pump, and on trying the experiment, he found that they had acquired a ſenſible degree of heat, by being rubbed for ſome time in vacuo.

Spirit of wine, ſulphur, gunpowder, and other ſubſtances that are eaſily inflammable, cannot be fired in vacuo. Some of them will be melted, and will ſmoke, but they don't ſhew any flame; and although they are rendered very volatile, yet they cannot be burned, as is eaſily effected in the open air. Aurum fulminans, or fulminating gold, heated by the focus of a burning-glaſs in an exhauſted receiver, goes off, and is ſcattered in the form of yellow duſt about the receiver.

Air is neceſſary to vegetation and germination of ſeeds. Not only in vacuo, but in much rarefied air, no plant can live. It is for want of the acceſs of air, that the ſeeds which are placed very deep under ground never vegetate. In air that is condenſed to a certain degree, ſome plants, it is ſaid, grow pretty well; but I don't know that experiments of this ſort have been often tried.

It ſeems natural to ſuppoſe, that good air, ſuch as is fit to ſupport animal life, and combuſtion, is the beſt for the growth of plants; nevertheleſs, ſome plants ſeem to vegetate exceedingly well in air that is unfit for reſpiration and combuſtion, though not rendered quite infected with putrid effluvia; for in ſuch air all the plants that have been actually tried, have been found to die preſently.

When growing plants, with their proper nouriſhment, as a pot with moiſt mold, &c. (which muſt be always underſtood, when we ſay that living plants are confined in any ſort of elaſtic fluid) are placed in confined air; for inſtance, under a glaſs receiver inverted in water or mercury; in general they vegetate pretty well, and for a long time, though they cannot be ſaid to be in a very flouriſhing ſtate. It has been obſerved, that in thoſe circumſtances the plants don't render the air in which they are confined, unfit for reſpiration or combuſtion; but Mr. Cygna, an ingenious philoſopher, ſays, that plants confined in a quantity of air, vegetate for a very ſhort time, and then die, diminiſhing at the ſame time the bulk of that quantity of air; which ſhews that the air has been vitiated thereby; it having been obſerved, that when air is diminiſhed by any proceſs, it is generally rendered leſs good. Mr. Cygna farther obſerves, that if other plants are introduced into the air, wherein the former plants periſhed, they ſoon die, but do not occaſion any farther diminution of that quantity of air. In ſuch experiments, great difference may ariſe from the diverſity of plants uſed, and the ſtate in which they are when firſt confined; there being many plants which do actually grow, and appear very flouriſhing, in places where the air is much infected; whereas other plants ſoon periſh in the ſame places, and cannot vegetate except where the air is pure and ventilated. But much light has been thrown upon this ſubject by ſeveral late experiments of the learned Dr. Priestley, and Dr. Ingenhousz, which will be mentioned in the ſequel.

The property of air, which more nearly intereſts human kind, is its being neceſſary for the ſupport of animal life. Not only the exiſtence of air is neceſſary, but it is alſo required to be good, and proper for reſpiration; otherwiſe, contaminated air is as noxious to an animal as a vacuum. Animals of every ſort, including even the microſcopical inſects, cannot live without air. Indeed ſome inſects, and eſpecially flies, waſps, &c. whoſe vital power is not eaſily loſt, although they may continue for a conſiderable time without internal or external ſenſible motion, do not die very ſoon under the exhauſted receiver of a common air-pump, but they die in a more perfect vacuum, as the Torricellian vacuum, or that made with a very good air-pump *.

Air a little compreſſed is not noxious to animal life; and it has been found, that when animals of the ſame ſort are put in equal receivers, ſome containing common, and others moderately-condenſed air; thoſe that were put in the latter, lived generally longer; but in air highly compreſſed, it ſeems, from ſome experiments, though not very numerous and accurate ones, that animals cannot live. This effect might be owing merely to a mechanical principle; for when the air is highly compreſſed, it will exert a greater preſſure upon the body of an animal, than can be counterbalanced by the elaſticity of the air within the body; hence it may be reaſonably ſuppoſed, that in ſuch caſe the free circulation of the fluids within the body may be retarded, and even quite ſuppreſſed.

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* The beſt air-pump to be had at preſent in London, is that made upon the principle of that great mechanical genius, Mr. Smeaton, F. R. S. It is ſaid, that an air-pump of a new conſtruction has been lately made in France, which exhauſts better than the above-mentioned one; but I could not yet procure a deſcription of its conſtruction.

It has been already mentioned, that air is contaminated by reſpiration as well as by combuſtion, and that a freſh ſupply is continually required to keep an animal alive, or a fire burning. It has been commonly obſerved, and is mentioned by various writers, that a gallon of common air cannot keep a middle-ſized candle burning for longer than one minute; and, upon an eaſy computation, it may be ſaid, that a man requires about 40 cubic inches of common air per minute, in order to breathe without uneaſineſs; but theſe quantities are ſubject to very great variations, ariſing from the nature of the perſon, as well as from the quality of the air, which is not only different in different places, but alters in the ſame place, according to the winds, ſeaſons, and perhaps other cauſes. There are animals that contaminate a quantity of air as highly, and in the ſame time, that other individuals of the ſame ſpecies, age, and ſize, contaminate half that quantity. The greateſt variations of this kind ariſe from the food, cleanlineſs, and health of the animal.

The contamination of air occaſioned by reſpiration is greater than that occaſioned by combuſtion; for an animal will live for ſome time in air that is contaminated by a burning candle, and wherein no candle will burn; but a candle will be immediately extinguiſhed when admitted in air rendered quite noxious by breathing. By both proceſſes, viz. by combuſtion and reſpiration, air is diminiſhed

miniſhed in bulk, but not ſo much by the former as by the latter.

The moſt intereſting of the above-mentioned properties of air, reſpecting animal life and combuſtion, will be illuſtrated by the following experiments, which the reader may eaſily perform, although he may not be furniſhed with particular apparatus.

EXPERIMENT I.

Stick a ſtraight piece of wax taper, about four inches long, upon a large cork, like D, fig. 16. Then take an empty common quart bottle AB, and hold it by the neck in an inverted ſituation. Light the wax taper, and very nimbly introduce it into the bottle, taking care not to put it out by touching the ſides of the neck of the bottle. The cork C being large, will cloſe the mouth of the bottle, and thus hinder that any change of air within the bottle might take place. In this ſituation the wax taper will ſoon begin to contract its flame, grows dim, and in about a quarter of a minute is extinguiſhed.—Withdraw the cork with the wax taper, and immediately cloſe the mouth of the bottle with the thumb of the hand that holds it.—Light the taper, and, ſlipping off the thumb, introduce it again into the bottle; but now it will be extinguiſhed immediately, becauſe the air within the bottle, being once vitiated, cannot aſſiſt the flame any longer. If it be ſuſpected that the wax taper is put out, becauſe the bottle is filled with the ſmoke produced the firſt time; the bottle, with the ſame contaminated air in it, may be kept for an hour, a day, or, in ſhort, for any length of time *, ſo as to let the fumes ſubſide, and the air become again tranſparent; and then the lighted wax taper may be introduced anew; but it will be conſtantly found, that its flame is put out the moment it is introduced.

EXPERIMENT II.

In the bottom of a baſin C D, fig. 17, put eight or ten pieces of money one upon the other, ſo as to make a ſmall pillar F, upon which put ſome cotton, or pieces of paper, with a little brimſtone E; and pour ſome water into the baſin, ſo as to reach the fifth or ſixth piece of money. Then invert a large and plain glaſs tumbler A B, upon the cotton and its ſupport, in the manner ſhewn in the figure. This tumbler ſhould be kept a little inclined in the act of putting it down, in order to let ſome water enter in it, and ſome air go out; otherwiſe the tumbler, when left, would hardly ſtand in the poſition required. On the outſide of the tumbler a mark ſhould be made, juſt coinciding with the level of the water within it. Now

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* In order to preſerve the contaminated air, the bottle ſhould be accurately corked, or it is ſufficient to put it inverted with the mouth in a cup full of water.

bring this apparatus in a place where the ſun ſhines, and by means of a lens G, which needs not be larger than three inches in diameter, throw the collected rays of the ſun acroſs the ſubſtance of the glaſs A B, upon the cotton and ſulphur E, which by that means will be inflamed; in which caſe the air within the glaſs tumbler A B, being rarefied by the heat, will depreſs the water under it, and ſometimes will force its way out, which accident ſhould be prevented by uſing a ſmall quantity of the combuſtible materials E, and by letting the water come pretty high within the tumbler, previous to the application of the lens. This ſhews another reaſon for which it was directed above to hold the glaſs A B ſomewhat inclined, viz. with the mouth not quite downwards, in the act of putting it down into the baſin, in order to let ſome water enter in it, and come as high as about the fourth or fifth piece of money.—After the combuſtion of the cotton, when the apparatus is become as cool as it was before, the water within the tumbler A B, will be found to be riſen above the mark; which ſhews that the combuſtion of the cotton or paper, &c. has occaſioned a diminution of the air within the glaſs A C.

It has been commonly thought and aſſerted, eſpecially by the writers of the laſt age, who were very well acquainted with this phenomenon, that combuſtion weakened the elaſticity of the air, and for this reaſon it was diminiſhed in bulk; but it will appear in the ſequel, that

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this diminution is owing to various cauſes. For the preſent we may reſt contented with the certainty of the fact, and with calling it ſimply a diminution of air occaſioned by combuſtion.

Some combuſtible ſubſtances, as gunpowder, and in general thoſe compoſitions wherein nitre enters, diſcharge a conſiderable quantity of elaſtic fluid in the act of burning, for which reaſon they cannot be uſed for this experiment.

EXPERIMENT III.

Invert the ſame glaſs tumbler A B, uſed in the foregoing experiment, into a baſin containing two or three inches depth of water, C D, fig. 18, and put a mouſe, or a bird E under it. The tumbler ſhould be kept ſteady with the hand, or by putting a weight upon it; and no great quantity of water ſhould be poured into the baſin, leſt it ſhould be ſuſpected that the animal is drowned by it, yet it ſhould be deep enough to admit the animal being put in and out of the tumbler through the water, without lifting the mouth of the tumbler above the ſurface of the water.—Keeping the apparatus thus diſpoſed, it will be obſerved, that the bird or mouſe does not ſhew any ſigns of uneaſineſs in the beginning, but in a ſhort time will begin to quicken its reſpiration, ſhewing ſome anxiety, and as if ſome impediment was in his throat.

This uneaſineſs will gradually increaſe, till at laſt the animal loſes its ſtrength, and drops down ſtaggering a little; but every motion will preſently ceaſe, excepting a weak opening and ſhutting of the mouth, and ſoon after the animal dies.

Let now this dead bird or mouſe be withdrawn, and another animal be introduced through the water into the tumbler A B*; and it will be found, that this ſecond animal will be affected with convulſions as ſoon as it is admitted into the contaminated air, and will preſently die; the air therefore contained in the veſſel AB, has been rendered highly noxious by reſpiration; and although it be kept for a long time, it will always retain its noxious quality. This fact being very well known by the philoſophers of the paſt age, it was by them explained upon the ſuppoſition, that the air did contain an enlivening principle *(a pabulum vitæ)*, neceſſary for the ſupport of animal life; that by the action of breathing, animals in every inſpiration ſeparated a portion of this principle from the air, and that when the air had thus, by animal reſpiration, been deprived of all the quantity of the enlivening principle it contained, it became unfit for reſpiration.

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* In order to take the dead animal out, or to put another animal in, without changing the air, the tumbler muſt be raiſed a little above the bottom of the baſin, taking care not to lift it above the ſurface of the water, and muſt be held with one hand in that ſituation; then the bird, mouſe, &c. is plunged under water, and is inſtantly paſſed under the glaſs A B, which glaſs may then be lowered again upon the bottom of the baſin.—The animal will not ſuffer any damage by being thus for a moment plunged under water.

Dr. PRIESTLY, who has examined this branch of natural philoſophy with unwearied aſſiduity and wonderful ſucceſs, treating of the air contaminated by reſpiration, makes the following excellent obſervations.

" When animals, *ſays he*, die upon being put into air " in which other animals have died, after breathing in it " as long as they could, it is plain that the cauſe of their " death is not the want of any *pabulum vitæ*, which has " been ſuppoſed to be contained in the air, but on ac- " count of the air being impregnated with ſomething " ſtimulating to their lungs; for they almoſt always die " in convulſions, and are ſometimes affected ſo ſuddenly, " that they are irrecoverable after a ſingle inſpiration, " though they be withdrawn immediately, and every me- " thod has been taken to bring them to life again. They " are affected in the ſame manner, when they are killed " in any other kind of noxious air that I have tried, viz. " fixed air, inflammable air, air filled with the fumes of " brimſtone, infected with putrid matter, in which a " mixture of iron filings and brimſtone has ſtood, or in " which charcoal has been burned, or metals calcined, or " in nitrous air, &c.

" As it is known that *convulſions* weaken and exhauſt " the vital powers, much more than the moſt vigorous " *voluntary* action of the muſcles, perhaps theſe univerſal

" convulſions may exhauſt the whole of what we may call " the *vis vitæ* at once; at leaſt that the lungs may be " rendered abſolutely incapable of action, till the animal " be ſuffocated, or be irrecoverable for want of reſpiration.

" If a mouſe (which is an animal that I have commonly made uſe of for the purpoſe of theſe experiments) can ſtand the firſt ſhock of this ſtimulus, or has " been habituated to it by degrees, it will live a conſiderable time in air in which other mice will die inſtantaneouſly. I have frequently found, that when a number of mice have been confined in a given quantity of " air, leſs than half the time that they have actually lived " in it, a freſh mouſe being introduced to them has been " inſtantly thrown into convulſions, and died. It is " evident, therefore, that if the experiment of the Black " Hole were to be repeated, a man would ſtand the better chance of ſurviving it, who ſhould enter at the firſt, " than at the laſt hour.

" I have alſo obſerved, that young mice will always " live much longer than old ones, or than thoſe which " are full grown, when they are confined in the ſame " quantity of air. I have ſometimes known a young " mouſe to live ſix hours in the ſame circumſtances in " which an old mouſe has not lived one *."

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* PRIESTLEY's Experiments and Obſervations on different kinds of air. Vol. I. Part I. Sect. IV.

EXPERIMENT IV.

In order to obſerve the diminution of air occaſioned by reſpiration, part of the preceding experiment ſhould be repeated; taking care to remark the quantity of air before and after the death of the animal. Thus, when the tumbler is inverted in water, and left to ſtand by itſelf with the animal in it, a mark ſhould be made upon it, coinciding with the level of the water within the tumbler. This mark muſt be made immediately, ſo that time might not be allowed for the air to be in part contaminated and already contracted in bulk. Soon after the death of the animal, the water within the tumbler will be found to be raiſed above the mark, which clearly ſhews that the bulk of the air has been contracted by reſpiration.

EXPERIMENT V.

By this experiment is to be ſhewn, that air, contaminated by a burning candle, and wherein a lighted candle is immediately extinguiſhed, is not ſo noxious to animal life, as the air contaminated by animals breathing and dying in it.

Let a ſmall bit of wax taper be lighted and incloſed under the glaſs tumbler A B, fig. 18, inverted in water, and when the flame is put out, in which caſe it was proved by the firſt experiment, that no other candle will burn in the ſame air; but if a ſmall animal be introduced in it, paſſing him through the water, in order that the air within the tumbler might not be changed, it will be found that the animal will live nearly as long in this air contaminated by the burning candle, as in an equal quantity of common unaltered air. But, on the contrary, in air that is rendered noxious by animals breathing and dying in it, a lighted candle will be put out immediately.

Although the burning of a candle does not contaminate the air ſo much as to render it quite unfit for reſpiration, yet it muſt not be underſtood that this is the conſtant effect of combuſtion in general; there being certain particular methods, to be deſcribed hereafter, by which combuſtion may be made to diminiſh and contaminate common air to the higheſt degree poſſible, ſo as to render it quite noxious to animals.

Combuſtion and reſpiration are not the only proceſſes which contaminate air. Putrefaction, efferveſcence, calcination of metals, &c. are alſo powerful means by which good common air is rendered noxious, and unfit for combuſtion and animal life.

Having in theſe few experiments and obſervations ſhewn the methods of obſerving ſome of the principal properties of air reſpecting combuſtion and reſpiration; we ſhall next take a ſhort and comprehenſive view of the various ſtates of the atmoſpherical fluid, as it naturally exiſts in various places.

From the obſervations mentioned in the preceding pages it appears, that the air at the top of mountains is much more rarefied than the air near the ſurface of the earth, which is alſo more rare than that at the bottoms of pits; and from the experiments performed with the air-pump and condenſing engine it will be eaſily deduced, that the denſe air at the bottoms of pits, and places that are nearer to the center of the earth, ought to be more fit for reſpiration and combuſtion, than the air which exiſts about the ſame level with the ſea, and much more ſo than the air upon very high mountains. Theſe deductions are however founded only upon the greater or leſs denſity of the air, ariſing from the preſſure of the ſuperincumbent air; but the common atmoſpherical air is ſubject to conſiderable diverſities, occaſioned by other cauſes far different from condenſation or rarefaction; for the air at different places, but of the ſame denſity, viz. where the barometer is equally high, is not of the ſame goodneſs.

It muſt be obſerved, that the common atmoſpherical air, which ſurrounds our globe, being ſubſervient to the reſpiration of ſo many animals, to the combuſtion of innumerable fires, as well artificial as natural, and being continually impregnated with the putrid effluvia and exhalations of every ſort, that are emitted by corrupting and fermenting matters; muſt of courſe be continually contaminated, and muſt gradually become more and more unfit for reſpiration and combuſtion. The contaminated air next to the bodies of animals, putreſcent ſubſtances, &c. is by the wind carried off and intermixed with the common ſtock; whilſt other purer air takes its place. Hence we ſee that the winds are of great uſe in the world, as they remove the tainted air which ſurrounds animals, habitations, towns, &c. the ſtagnation of which would otherwiſe be attended with very bad conſequences; for, *cæteris paribus*, the air of a place is more or leſs pure, according as it is more or leſs ventilated.

The contaminated air thus by winds removed from the places where it has been contaminated, and being intermixed with the reſt of the atmoſphere, is not by that motion purified; as we find that a very long agitation of a mixture of common and tainted air does by no means purify it; but being continually added to the common ſtock muſt gradually tend to contaminate the whole atmoſphere; which conſideration naturally offers the following dilemma, viz. that either nature has provided ſome methods to purify the atmoſphere continually, or that the air at preſent is worſe than it was in former ages, and much better than it will be one hundred or a thouſand years hence. Had the ancients known ſome certain method to diſcover the degree of purity of the air, and had they left us any account of their obſervations, we might perhaps eaſily anſwer the queſtion; but this not being the caſe, we muſt be contented with the experiments and obſervations of this age, in which the methods of aſcertaining the degree of purity of the air, have been diſcovered, and brought to a great degree of preciſion. The people of the next century may, by comparing our obſervations with theirs, acquire a much better knowledge relative to the decreaſe or increaſe of the atmoſphere's purity.

That nature has provided ſome means to purify the atmoſphere, has been long ago believed, and ſeveral odd explanations have been offered *; but ſome very intereſting diſcoveries have been lately made in reſpect to this point, and will be particularly noticed in proper places.

Ventilation, as we obſerved above, occaſions great diverſity in the goodneſs of the air of a place; and it is owing to this cauſe that the air on the top of high mountains,

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* The learned Father Kircher, fully perſuaded of the wrong notion prevailing at his times, viz. that inſects were produced by putrefaction, ſuppoſes that contaminated air is purified by the production of thoſe animalcules; viz. that the putrid and offenſive particles collecting together, formed the bodies of theſe animalcules, in conſequence of which the air remained as pure as it was before the impregnation of thoſe particles. "In aere vero, uti ex putredinis "virulentæ exhalatione ſemper quoddam virulentum nidulatur, ita quoque "primo de inſectis quibuſdam natura providit, quæ putredinoſo confluxu, "exquo originem ſuam traxerunt, in ſe derivato aërem quodammodo purgarent: cujuſmodi ſunt muſcæ, aranei, veſpæ omnia alatorum inſectorum "genera, ex aquæ putredine ortum necta, quæ poſtea in hirundinum, veſpertilionumque, et ſimilium animantium alimentum cedunt.—Kircheri Mundus "ſubterraneus, Lib. IX. Cap. II.

tains, although very much rarefied, is yet, in general, fitter for reſpiration than the ſtagnant air at the bottoms of pits; the former being continually changed, but the latter having very little motion and intermixture with the reſt of the atmoſphere*. Various perſons, eſpecially after being uſed to it a little, have lived very well upon high mountains, where the air was ſo rare that the quickſilver in the barometer did not ſtand higher than 15 or 16 inches †.

In places that are below the level of the ſea, eſpecially mines of coal and metals, the air is depraved by the mixture of certain effluvia diſcharged from the earth, which, for want of ventilation, ſometimes remain in thoſe places for a conſiderable time, and are ſo far noxious, that perſons, who work in mines, are often ſuffocated by them. Theſe exhalations are not ſimply formed of vapours condenſable by cold into viſible fluids; but conſiſt chiefly, if not wholly, of permanently elaſtic fluids, which have various peculiar properties, different from thoſe of common air, either when fit for reſpiration, or when contaminated by reſpiration and combuſtion.

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[*] Whenever mention is made of ſtagnating air being noxious, it muſt be underſtood, that in this caſe the air is noxious ſo far as it retains the bad effluvia, which are communicated to it either previous, or whilſt it is confined; for mere confination does not render common air better or worſe; ſo that a quantity of common air kept for a long time in a clean glaſs bottle accurately ſtopped, as far as it has been obſerved, does not thereby grow better or worſe than it was before.

[†] *See* BOUGER's Voyage to Peru.

The emiſſion of thoſe permanently elaſtic fluids is not only obſervable in mines and other ſubterraneal places, but takes place alſo in various parts of the ſurface of the earth, eſpecially near volcanoes, ſtagnating water, putrid marſhes, &c. The great difference is, that in the former places they are not eaſily ventilated, whereas in the latter the wind more eaſily diſperſes them, or, from their being much lighter than the atmoſpherical air, they aſcend to the upper regions as ſoon as they are diſcharged.

Miners have been long acquainted with the exiſtence of thoſe noxious fluids in ſubterraneal places, and diſtinguiſh them by the appellation of *damp*, which word originally ſignifies *vapour* or *exhalation*. It has been alſo well known, that ſome of thoſe damps are periodical, appearing at intervals of time, whilſt others exiſted continually in ſome places, which on that account became impracticable.

Accounts of the effects of thoſe damps are to be met with in many books, in which real facts are often mixed with marvellous exaggerated ſtories, moſtly deſcribing the number of people killed in particular inſtances; the various methods of recovering thoſe who are at firſt affected by them; the precautions that miners take in order to diſtinguiſh the actual exiſtence or approach of damps, &c. But thoſe particular precautions bring moſtly random practices, without much foundation in reaſon or experience, are not deſerving my reader's notice, except a few, which are proper and uſeful, and will be mentioned preſently.

Different authors enumerate various ſorts of damps, their diverſity ariſing principally from their various degrees of intenſity; but very few from being eſſentially different from each other. Some reckon four kinds of damps, viz. one whoſe approach is diſtinguiſhed by the flame of candles becoming firſt dim, and then being extinguiſhed; from the difficulty of breathing, &c. The ſecond kind, is ſaid to be called the *peaſe-bloom damp*, from its ſmell; which damp is not ſo bad as to deſtroy people. The third ſpecies is the ſtrangeſt of them all, if it is at all to be credited. Some perſons, who pretend to have ſeen it, deſcribe it in the following manner:—In the higheſt parts of the roof of ſome of thoſe paſſages, which branch out of the main grove of a mine, a round ſort of bag is ſeen hanging, about the bigneſs of a foot-ball, formed of a film that much reſembles a cobweb. Whenever this bag happens to be broke, the noxious fluid which forms the damp flies out, and ſuffocates all the perſons who happen to be near it. The fourth ſort of damp, which is more frequently met with in coal-mines, is called the *fulminating*, or *fire-damp*, from its property of taking fire by the approach of flame, and exploding.

After all, the damps hitherto known and examined by intelligent people, may be reduced to two, which conſiſt of permanently elaſtic fluids different from each other, and different from common air, but agreeing only in the properties of elaſticity and tranſparency. One of theſe fluids is heavier than common air, for which reaſon it is found at the bottoms of pits and mines. It extinguiſhes flame, and ſuffocates animals, for which reaſon it has been commonly called the *choke-damp.* The other fluid is much lighter than common atmoſpherical air, and is found in the roofs of ſubterraneous places, which prevent its eſcape into the higher regions of the atmoſphere. This permanently elaſtic fluid takes fire by the approach of the flame of a candle, and explodes with violence and noiſe; for which reaſon it has been called the *fire-damp.* This ſort of elaſtic fluid, although highly noxious when breathed by itſelf, is not very offenſive when mixed with ſome common air; and as it is commonly found in this mixed ſtate in mines, it has not been eſteemed dangerous, except when it catches fire and explodes, in which caſe it kills the people near, &c. The miners, therefore, whenever they are apprized of the exiſtence of this damp, which they diſtinguiſh by the particular ſmell of that fluid, always forbear to bring any lights near it*.

Whenever they have any ſuſpicion of the choke-damp, they generally let down a candle very near the ground; which if it is extinguiſhed ſhews the exiſtence of the damp, and how high it reaches. In thoſe caſes the beſt remedy is ventilation. When it is practicable, it is a very good expedient to ventilate the air of a mine by a fire. It has been propoſed by ſome ingenious perſons, and I hear that it has been alſo practiſed, to ſet fire to, and explode the fire-damps by matches, and other contrivances, and thus free the mines from the dangerous fluid; but ſometimes the production of thoſe permanently elaſtic fluids from the bowels of the earth is ſo abundant, that all the practicable means of ventilation, &c. are not ſufficient to keep pace with their production; for which reaſon thoſe mines muſt be abandoned. The moſt alarming and dangerous caſes of this ſort, are when thoſe noxious fluids are emitted at once, without giving any previous ſigns, which is often known to happen. Then the miners, except they can get out of the mine immediately, muſt inevitably periſh. It ſeems poſſible to contrive ſome means of ſafety, viz. ſome kind of bags, containing good reſpirable air, which the miners might keep always near, and in caſe of danger might apply them to their mouths till they can get out of the mine, and thus be not obliged to breathe the noxious fluid, and conſequently eſcape being ſuffocated; but of theſe poſſible means of preſervation we ſhall take notice towards the end of this work, viz. after that the peculiar properties of permanently elaſtic fluids have been particularly conſidered.

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* It is a common practice amongſt the miners, to try the hardneſs of ſtones by ſtriking them againſt a ſteel, and obſerving if they produce any ſparks of fire. This practice ſhould not be permitted near the fire-damp; it having been lately obſerved, that even a ſpark of that ſort is ſometimes ſufficient to inflame that elaſtic fluid.

An elaſtic fluid, like that which conſtitutes the choke-damp, is found in many places upon the ſurface of the earth, eſpecially near the ſpring of ſeveral mineral waters; which being moſtly impregnated with that fluid, diſcharge a conſiderable quantity of it, as ſoon as they come out of the earth.

In the kingdom of Naples, and not more than ſix or ſeven miles from the capital of that kingdom, is a famous cave, near the foot of a hill, called in the Italian language *grotta del cane*. This grotto is about fourteen feet long, and near ſeven feet high at the entrance. On the floor of it, there is always a ſtratum of that elaſtic fluid, which conſtitutes the choke-damp. It is continually emitted from the earth, through the fiſſures that may be ſeen on the ground. The experiments uſually ſhewn to the curious, who viſit this grotto, are, firſt, that of bringing a lighted candle or piece of paper near the floor, which is put out as ſoon as it comes within about 14 inches of the ground; and, ſecondly, that of keeping a dog with its head near the ground, for about a minute, ſo as to oblige him to breathe the noxious fluid, which will ſoon affect his reſpiration, deprive him of his ſtrength, and would ſoon kill him, if he was not immediately brought out into the open air; where, if he is not too far gone, he will gradually recover ſtrength and freedom of reſpiration *. There is a ſmall lake near this grotto, the water of which is conſidered as a ſpecific againſt the effects of the noxious fluid of the grotto, ſo that the animals apparently killed, or too much affected by that fluid, may be ſoon recovered by being bathed in that water; but if it is true that thoſe waters at all contribute to reſtore the animals thus affected, it ſeems to be merely by the ſhock they give with the ſenſation of cold.

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* From this experiment of the dog, the cave derives its name of *grotta del cane*; the Italian word for *dog* being *cane*.

The ſoil about this cave is full of hot, ſulphurous, and offenſive emanations, and is not far from the *Solfatara*, a place containing various ſmall hills and valleys, almoſt wholly impregnated with ſulphur, which mineral is extracted from that ground with conſiderable profit. In various parts about thoſe hills, and eſpecially in the principal valley between them, there are various emanations of ſmoke, flame, noxious vapours, hot waters, and other ſigns of ſubterraneal fire and fermentation.

Thoſe two above-mentioned elaſtic fluids, which conſtitute the damps, and are different from common air, or from air contaminated by reſpiration, may be obtained by art from ſeveral ſubſtances; and the inveſtigation of their properties has ſhewn, that beſides them, many other permanently elaſtic fluids may be obtained by means of different proceſſes; which have properties peculiar to each, and may be turned to various uſes highly intereſting in philoſophy, as well as for the general welfare of the human ſpecies. Thoſe various elaſtic fluids will be enumerated in the next chapter; and we ſhall conclude the preſent with a few obſervations concerning the contagious diſeaſes commonly attributed to the air.

Mr. Boyle, conſidering that the plague, although it happens ofteneſt in hot climates, yet it has not been obſerved to viſit equally thoſe places which are alike ſituated in reſpect to climate, and other apparent circumſtances; ſeems inclined to think that the plague, and its effects, are occaſioned by a malignant diſpoſition in the air; without which, he obſerves, ſome plagues could never have been ſo contagious, nor ſo ſuddenly mortal; and that this malignant diſpoſition in the air, may probably be in great part imputed to ſome kinds of ſubterraneal expirations *.

There are ſome hiſtories of plagues originating from the opening of old burying-places, wherein people who died in the time of former plagues, had been interred; and it is certain that the venomous effluvia in a true peſtilential contagion, are often tranſmitted from patients to ſound perſons, through the air only; for in ſuch times many perſons are taken ill without having had any intercourſe with affected people. But leaving the particular effects and origin of plagues to be examined in the writings of thoſe numerous authors, who have written expreſsly upon the ſubject; I ſhall only obſerve with reſpect to the air, that a very great diſtinction ſhould be made between air contaminated by the mixture of thoſe ſubſtances, which will incorporate intimately with it, and thoſe which are only ſo far

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* See Boyle's Works by Dr. Shaw, the ſecond edition, page 533.

mixible with the air, as to be ſuſpended in that fluid on account of their being very light and volatile, and which are eaſily ſeparated from it as ſoon as they or the air change denſity, or the air is ſtrained through ſubſtances which abſorb, condenſe, intercept them, &c. In this ſenſe it is not difficult to ſuppoſe that the air may become peſtilential by keeping ſuſpended putrid effluvia of infected bodies; juſt as it may be rendered poiſonous by the vapour of arſenic. This depravity of the air, occaſioned by the accidental ſuſpenſion of noxious particles, (which however do not incorporate with it) is of great conſequence to the life of animals that breathe it, and yet is generally of ſuch nature, that it cannot be diſcovered by the common teſt uſed now-a-days to diſtinguiſh the purity of the air, with thoſe inſtruments called *eudiometers*, to be deſcribed hereafter. In the ſame manner the air may be impregnated with ſalutary effluvia, which when conveyed with it into the human body prove very beneficial; and yet by the above-mentioned teſt the air will be found, as it really is, to be not eſſentially better than before.

I ſhall juſt illuſtrate this intereſting property by a familiar example, and then ſhall finiſh this long chapter. Suppoſe that ſome white lead is dropped in water, and the water is immediately drank, it will certainly poiſon the perſon that drinks it, becauſe the particles of white lead, which are poiſonous, being ſuſpended in the water, are conveyed with it into the body; but not becauſe

cauſe the nature of the water is altered thereby; for water will not incorporate with white lead, and if time be allowed for the particles of white lead to fall to the bottom of the veſſel in virtue of their own gravity, the water will remain pure over it, and may be drank without danger; but if, inſtead of white lead, ſome vitriolic acid be mixed with water, this acid, although ſpecifically heavier than water, will incorporate with it very readily and intimately, on account of the natural affinity or attraction between the particles of vitriolic acid and of water; and although the mixture be kept for a long time, yet the vitriolic acid will not fall to the bottom of the veſſel, but will incorporate with the water, and will communicate to every portion of it an equally acid quality.

CHAP. IV.

Of the various ſorts of permanently elaſtic Fluids.

WHOEVER conſiders that permanently elaſtic fluids, different from common air, are produced from fermentation, combuſtion, putrefaction, and are naturally found in various parts of the earth; and conſequently muſt have been coeval with human kind; cannot help wondering, when he is told, that no diſtinct idea, neither any direct mention of them is found in the works of writers previous to PARACELSUS, who flouriſhed about the beginning of the laſt century. Indeed, the notion that PARACELSUS and his cotemporaries had of the elaſtic matter that eſcaped from various proceſſes, was very confuſed and erroneous. They thought it to be the ſame thing with the common reſpirable air; but yet they gave it a particular name, calling it *ſpiritus ſilveſtris*. VAN HELMONT, a writer of the laſt century, and a diſciple of PARACELSUS, was the firſt who made diſtinct mention of various ſorts of permanently elaſtic fluids different from common air, to the whole genus of which he gave the name *gas*, which word, as it has been already obſerved, originally ſignifies a windy eruption; and diſtinguiſhed each ſpecies by particular deſcriptive words added to the generic one. This author enumerates various gaſes, as the *gas ſilveſtre*, the *gas flammeum*, the *gas ventoſum*, *gas pingue*, &c.; which elaſtic fluids, although differently originated, yet in ſubſtance they are reduced to a few elaſtic fluids really different from each other, and moſtly known under other names. This ſagacious author juſtly obſerved, that the elaſtic, and, as he calls it, incoercible fluid produced by different proceſſes, and into which ſome bodies are almoſt entirely reſolvable, could not be reduced into a viſible form, and alſo that it could not poſſibly exiſt in an elaſtic form, in thoſe bodies from which it was ſeparated, it being impoſſible for thoſe ſubſtances to remain ſolid in that caſe; but that it exiſted in a concrete or coagulated form *. He attributed the noxious effects of the *grotta del cane*, near the city of Naples, to the gas there exiſting, and applied the theory of the production of gaſes to explain various phenomena of the animal œconomy †.—Conſidering the time in which VAN HELMONT wrote, the ſcanty uſe of experiments that was made at that time, and the indiſtinct, vain, and ſuperſtitious notions then prevailing, it is a wonder that he acquired ſuch ideas of this ſubject. But the author of an ingenious treatiſe on the various kinds of permanently elaſtic fluids or gaſes, juſtly obſerves, " That VAN HELMONT's knowledge of theſe fluids " does not ſeem to have had much foundation in experi-" ment, or any other ſupport than the caſual obſervation " of an ingenious man, more intent on framing theories " than eſtabliſhing new facts. For when his doctrines " became exploded, the facts he mentions were ſo neg-" lected, that notwithſtanding the exiſtence of ſo many " gaſes is aſſerted by him, I do not believe that his writ-" ings ſuggeſted the idea of any one of them, to thoſe who

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* Corpora vero continent hunc ſpiritum, et quandoque tota, in ejuſmodi ſpiritum abſcedunt, non quidem quod actu in ipſis ſit (ſiquidem detineri non poſſet, imo totum concretum ſimul evolaret) ſed eſt ſpiritus concretus, et corporis more coagulatus, excitaturque acquiſito fermento, ut in vino, omphacio, pane, hydromelite, &c. Van HELMONTII Complexionum atque miſtionum Elementalium Figmentum Num°. 14.

† See his Treatiſe de Flatibus.

" afterwards diſcovered them: and it is now only, ſince " their exiſtence has been again diſcovered and aſcertained, " that we trace them in the works of this author, as a " matter of curioſity. While therefore we applaud the " ſagacity of VAN HELMONT, in having obſerved the exiſtence of many permanently elaſtic fluids, and in diſtinguiſhing them from condenſable vapours, and alſo from " air, we ought not, in juſtice, to make any abatement " from the honour due to BOYLE and his ſucceſſors, who " afterwards diſcovered the exiſtence and properties of " theſe fluids, collected them in ſeparate veſſels, ſubjected " them to various modes of experiment, and thence made " applications to explain the phenomena of nature."

BOYLE, the indefatigable promoter of experimental philoſophy, with the aid of the air-pump and condenſing engine, then new inſtruments, began to examine the ſubject of air, and other permanently elaſtic fluids, which, different from VAN HELMONT, he called *factitious airs.* His example was followed by many other able philoſophers, among whom the moſt diſtinguiſhed is Mr. HALES, whoſe name will be always an honour to this nation, as his ingenious, accurate, and numerous experiments have contributed vaſtly to the advancement of philoſophy. Thus, from the time of VAN HELMONT, the ſubject of permanently elaſtic fluids has been handed down through labourers continually increaſing in number, experiments, and fertility of diſcoveries, to the numerous philoſophers of the preſent age, who ſeem almoſt intirely devoted to this branch of natural philoſophy, and who, furniſhed with all the improvements of their predeceſſors, and prompted by a glorious emulation, advance every day the bounds of our knowledge relating to elaſtic fluids.

After having mentioned ſome of the firſt promoters of this ſubject, it would be natural, and but juſtice, to take notice of the philoſophers of our age, who have diſtinguiſhed themſelves in this ample field. However, their number, and the fear of offending, detains my pen; and as my object is not to write an hiſtory, but only a methodical treatiſe on air, and other permanently elaſtic fluids, I muſt avoid expatiating upon things foreign to my object, and which would neceſſarily occupy many pages of this work.

The elaſtic fluids hitherto diſcovered, with the principal various names given them by different authors, are thoſe that follow, excepting only a few, which have been very imperfectly deſcribed, and which will be mentioned towards the latter end of this work.

1. Air, or common air, or atmoſpherical air.
2. Fixed or fixable air, or aerial acid.
3. Inflammable air.
4. Nitrous air.
5. Dephlogiſticated air.
6. Vitriolic acid air.

7. Marine acid air.
8. Nitrous acid air.
9. Fluor acid air, or ſparry air.
10. Alkaline air.

Theſe elaſtic fluids, excepting common air, and dephlogiſticated air, are called alſo *gaſes*, with their diſtinguiſhing epithets, as *vitriolic acid gas*, *inflammable gas*, &c.

Fixed air has ſometimes been called alſo *mephitic air*. This word, however, is applicable to every ſort of elaſtic fluid, incapable of aſſiſting combuſtion and reſpiration, denoting only the noxious quality of the fluid. The noxious fluid naturally found in mines and other places, which does ſeldom conſiſt of pure fixed air, or other ſingle elaſtic fluid, has been commonly called *mephitic air*.

The dephlogiſticated air has been alſo called *pure factitious* air.

To prevent ambiguity and circumlocution, the reader is requeſted to mind, that in the following pages, whenever the word *air* is ſingly mentioned, without any other epithet annexed, it is only meant to denote common atmoſpherical air.

Some of the principal properties of common air having been mentioned in the preceding chapter, it remains to deſcribe the principal properties of the other permanently elaſtic fluids, which may diſtinguiſh them from each other, and which the reader ſhould make himſelf perfectly maſter of, in order that he may form a proper idea of the ſubject, and may underſtand the following part with greater facility.

Firſt, all the above-mentioned elaſtic fluids are tranſparent, ſo that by themſelves they are inviſible; but in ſome circumſtances, eſpecially on ſome of them being mixed, ſome colour may be perceived.

Secondly, if common air and dephlogiſticated air be excepted, they are all incapable of aſſiſting combuſtion and animal life.

Thirdly, common air, dephlogiſticated, inflammable, and nitrous air, are difficultly, and in ſmall quantities, abſorbed by water. Fixed air is in great quantity, and more eaſily, abſorbed by water; ſo that when it is agitated in it, a quantity of water will abſorb a quantity of fixed air about equal to its own bulk; by which impregnation the water acquires an acidulous taſte, much reſembling the taſte of ſome mineral waters, which are naturally impregnated with fixed air. The other elaſtic fluids, namely, the vitriolic acid air, the marine acid air, the nitrous acid air, the fluor acid air, and the alkaline air, are in vaſt quantity, and almoſt inſtantly, abſorbed by water; for which reaſon they cannot be confined by it. By this impregnation the water acquires an alkaline taſte from the alkaline air, and an acid taſte from the acid airs; which acid or alkaline taſtes are ſtronger or weaker, according to the greater or leſs quantity of elaſtic fluid imbibed by the water. All theſe acid elaſtic fluids have the principal properties of thoſe acids from which they are originated, and the alkaline air has the properties of an alkali; and they all have peculiar ſtrong, penetrating, and offenſive ſmells.

The principal ſpecific properties of each of thoſe elaſtic fluids are the following:

Fixed air is conſiderably heavier than common air; it has all the properties of an acid, but it is the weakeſt of all the known acids. It precipitates the lime in lime-water.

Inflammable air is much lighter than common air, has a particular diſagreeable ſmell, and by the contact of ignited bodies it takes fire very eaſily, and burns with a weak flame.

Nitrous air has a ſtrong, penetrating, and offenſive ſmell, and when mixed with common, or with dephlogiſticated air, occaſions a weak effervescence, which, while it laſts, the compound of the two elaſtic fluids acquires a reddiſh colour, and a diminution of the whole quantity takes place; which diminution is greater when the air is purer, and contrariwiſe, but is greateſt with dephlogiſticated air. Thus, if a given quantity of common air, which we may call A, be put, together with an equal quantity of nitrous air, in a veſſel, the bulk of both theſe elaſtic fluids together will be leſs than twice A, and leſs ſtill, if dephlogiſticated air is uſed inſtead of common air.

Upon the ſuppoſition that common air is only pure elementary air, partly contaminated or phlogiſticated, the name of *dephlogiſticated* air has been given to a particular ſort of elaſtic fluid, which poſſeſſes the property of aſſiſting combuſtion and animal life in a far more eminent degree than common air. A candle will continue burning, and an animal will live in a given quantity of it, much longer than in an equal quantity of common air. The diminution ariſing from the addition of nitrous air, as we obſerved above, is a vaſt deal greater with this than with common air. But it muſt be remarked, that we have no artificial method of obtaining dephlogiſticated air from common air; and that dephlogiſticated air has a property, to be mentioned hereafter, by which it appears that common air is an elaſtic fluid different from depraved dephlogiſticated air.

The vitriolic acid air, being abſorbed by charcoal, communicates to it a pungent ſmell. It diſſolves camphor very eaſily, reducing it into a tranſparent liquor, out of which the camphor may be again produced by the addition of water. On being mixed with the vapour of volatile alkali, it forms a white cloud.

Marine acid air, when abſorbed by water, forms a ſpirit of ſea-ſalt, whoſe ſtrength is in proportion to the quantity of elaſtic fluid abſorbed by the water; and as the quantity of it, which water can abſorb, is very great, a ſtronger ſpirit of ſalt may be obtained by this means, than by any other method. The flame of any burning ſubſtance acquires a beautiful green or blueiſh colour, when it burns in a mixture of this acid elaſtic fluid and common air.

The nitrous acid air has been leſs examined than any of the above-mentioned elaſtic fluids. It is inſtantly abſorbed by water, and corrodes quickſilver. When united with expreſſed oils, it gives them a blue and yellow colour, and coagulates them. Heat and effervefcence is produced by its combination with eſſential oils. It is imbibed by vitriolic acid and ſpirit of ſalt; ſo that the farther inveſtigation of its properties is impeded by the want of a fluid capable of confining it. However, it ſeems pretty well determined, that it is a permanently elaſtic fluid; at leaſt not condenſible by the cold to which it has been hitherto expoſed; which thing muſt be alſo underſtood of all the other kinds of fluids, called permanently elaſtic; by no means implying the impoſſibility of condenſing any of them, or all, into viſible fluids or ſolids by a greater degree of cold than has been hitherto employed for ſuch experiments.

The fluor acid air, or ſparry air, when expoſed to water, a part of it is inſtantly abſorbed by the water, and at the ſame time a ſtony film or cruſt is formed upon the ſurface of the water, which hinders the farther abſorption of the acid air; but on breaking this film, the water abſorbs another portion of it, and another film is formed. Thus, by breaking the ſtony film as often as it is formed, the water may be made to imbibe the whole of a given quantity of fluor acid gas expoſed to it. By means of heat, an acid elaſtic fluid is ſeparated from the water thus impregnated, which, on being abſorbed again by water, does not depoſit any cruſt as before, and beſides it poſſeſſes all the properties of vitriolic acid gas; hence it has been ſuppoſed, that fluor acid air is not eſſentially different from vitriolic acid air, but only charged with an earthy ſubſtance, which it readily depoſits as ſoon as it is abſorbed by water. But yet there are ſome differences between thoſe two acid gaſes, the principal of which is that remarked by Dr. Priestley, viz. that water impregnated with vitriolic acid air may be converted into ice by cold, but the water impregnated with fluor acid air may not.

Alkaline air, when abſorbed by water, forms a ſtrong ſpirit of volatile alkali. It diſſolves ice exceedingly faſt. It unites with vitriolic, and with marine acid air, with which it forms ammoniacal ſalts; and it unites alſo with fixed air, forming oblong ſlender cryſtals with it. When alkaline and common air are mixed together, the compound becomes inflammable.

The eaſy methods of procuring thoſe elaſtic fluids, and of obſerving their above-mentioned properties, will be ſhewn in the following experiments.

EXPERIMENT I.

To produce fixed Air.

Let a glaſs tube, open at both ends, be bent, by means of a blow-pipe and the flame of a candle, nearly into the ſhape of an S, as it is repreſented by A B, fig. 19, and fix a cork D to one of its extremities, ſo as to fit the neck of a common vial, that may hold about four or five ounces meaſure. The hole through the cork may be made with an iron wire red-hot, and the tube may be faſtened in it with a bit of ſoft wax, ſo as not to let any air go through*. Fill a ſimilar vial, or any glaſs receiver K, with water, and invert it after the manner ſhewn above, in a baſin H I, about half filled with water. Now put ſome chalk or marble, groſsly powdered, into the bottle E, ſo as to fill about a fourth or fifth part of it, and upon it pour ſome water, juſt enough to cover the chalk; then add ſome oil of vitriol to it, which needs not be more than about the fourth or fifth part of the water. Immediately after, apply the cork D, with the tube A B, to the bottle, and putting it in the ſituation F G, let the extremity B of the tube paſs through the water of the baſin into the neck of the bottle K, which now muſt be kept up with the hand, or other convenient ſupport, as it cannot reſt upon the bottom of the baſin. The mixture of chalk, &c. in the bottle F G, will immediately begin to effervefce, ſhewing a frothing, and an inteſtine motion accompanied with heat, that may be felt by applying the hand to the outſide of the bottle. The elaſtic fluid called *fixed air* is copiouſly emitted from this mixture, and paſſing through the bent tube, will go into the bottle K, as appears by the bubbles which come out of the tube, and, paſſing through the water, aſcend to the top of the inverted bottle. In proportion as the elaſtic fluid fills the bottle K, the water gradually deſcends, and at laſt is quite expelled from it; the bottle K then is filled with fixed air, and being corked under water, may be removed from the baſin, and kept for uſe *. Another bottle may then be filled with water, and may be inverted over the extremity of the bent tube in the place of K, which other bottle may be filled in a ſimilar manner, and ſo on till the mixture in F G has finiſhed to yield any fixed air *.

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* Glaſs bottles, with a tube properly ſhaped for this purpoſe, having a grinted glaſs ſtopper affixed, which fits the neck of the bottle very nicely, may be found at various glaſs ſhops, and almoſt at any of the philoſophical inſtrument ſhops in London.

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* When bottles, filled with ſome elaſtic fluid, are to be kept for a conſiderable time, the beſt method is to leave a ſmall quantity of water in them, and then they muſt be kept with the corked mouth downward, the water ſerving to prevent more effectually the eſcape of the elaſtic fluid through the ſides of the ſtopper and the neck of the bottle.

If one of theſe bottles filled with fixed air be uncorked, and holding it with the mouth upwards, a lighted wax taper, bent like L, or a ſmall piece of it affixed to the extremity of a wire, be immediately let down in it, the flame will be inſtantly extinguiſhed. The ſame thing will happen if a lighted piece of wood is let down in it.

Take a clean bowl, and putting the mouth of a bottle, filled with fixed air, in it, uncork it, and keep it in that ſituation for about a minute. The fixed air being ſpecifically heavier than common air, will come out of the bottle, and will remain at the bottom of the bowl, whilſt common air enters into the bottle; which bottle may now be removed, and, in order to ſhew the real exiſtence of the fixed air, which will immediately ſhew its being heavier than common air, put a lighted wax taper into the bowl, pretty near its bottom, which taper will be extinguiſhed immediately. The air in this experiment muſt be agitated as little as it is poſſible. That the flame of the wax taper was really extinguiſhed by the fixed air, may be eaſily proved in the following manner:—Blow once or twice into the bowl, by which means the fixed air will be expelled from it, and then, on letting down a lighted wax taper in it, as before, it will be found that it is

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* The effervefcence in the bottle F G, if required, may be renewed, by pouring a little more oil of vitriol in it.

no longer extinguiſhed, but will burn very well, the bowl being now filled with common air. This experiment never fails of ſurpriſing the ſpectators, as it clearly exhibits two remarkable properties of a fluid, which they can neither ſee, nor diſtinguiſh by the feeling.

When the bottle K is about half filled with fixed air, put a mark with a bit of ſoft wax on the outſide of it, juſt coinciding with the level of the water in it, and immediately after ſhake the bottle; but taking care that its mouth be not lifted above the ſurface of the water in the baſin. After having ſhaked it for about a minute, on intermitting the agitation, it will be found that the water is above the mark, which ſhews that ſome of the fixed air has been abſorbed by it *. Let this abſorption be carried on as far as poſſible, by agitating the bottle repeatedly, and allowing time to let more fixed air be produced, and enter into the bottle, in proportion as the water abſorbs it. Then apply the hand, or a finger, to the mouth of the bottle whilſt under water; bring the bottle out, and turn it with the mouth upwards. The water then will be found to have acquired a pleaſant acidulous taſte. The water thus impregnated with fixed air changes the blue

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* If the production of fixed air from the effervefcing mixture in the bottle F G is very copious, then, on eſtimating the abſorbtion from the mark, &c. a proper allowance ſhould be made for that quantity of fixed air that has been produced ſince putting the mark, and whilſt the bottle has been kept in agitation.

infuſion of ſome vegetable ſubſtances into red; ſo that if a weak ſolution of heliotrope is mixed with it, or, indeed, if it is ſimply expoſed to fixed air, the liquor acquires a reddiſh appearance. It alſo corrodes iron, and ſome other metals, much more eaſily than common water. But the greateſt and moſt uſeful property of this acidulated water, or water impregnated with fixed air, is its being a powerful *antiſeptic*, or corrector of putrefaction; ſo that being uſed internally for various diſorders incident to the human body, it has proved beneficial in a great many inſtances, in which other medicines failed. As the moſt uſed mineral waters are medicinal principally on account of their being impregnated with fixed air; beſides which, they generally contain ſome ſmall portion of metal or ſalt, diſſolved; they may be imitated by impregnating water with fixed air, and then adding that quantity of ſalt, or of metal, that, by analyſis, the original mineral waters are found to contain.

Not only the water impregnated with fixed air, but the fixed air itſelf, has been ſucceſsfully uſed as a medicine in caſes of putrid diſeaſes. When uſed for external caſes, the affected part has been commonly expoſed to the fixed air emitted by fermenting liquors, or by the mixture of calcareous ſubſtances, efferveſcing with diluted oil of vitriol in an open veſſel. When it is to be applied internally, the fixed air is received in a bladder, and then applying a proper pipe to the bladder, the gas is introduced into the body of the patient by way of gliſters. The method of getting this elaſtic fluid into the bladder is the following:—The pipe is firſt tied into the neck of the bladder, then a perforated cork is fixed upon the bottle containing the chalk and diluted vitriolic acid, and the pipe that is faſtened to the bladder is introduced faſt into the cork; but the bladder ſhould be firſt accurately compreſſed with the hand, ſo as to expel from it all the common air it contains. See fig. 20. In this ſituation, as the fixed air is detached from the effervеſcing mixture, it enters through the pipe into the bladder, which will thereby become gradually inflated, and when it appears full, its neck muſt be compreſſed, and the pipe is ſlipped from the cork; after which another empty bladder may be applied to the bottle, which will be filled in a ſimilar manner, &c. As the neck of the bladder filled with fixed air muſt be kept compreſſed, till the fixed air is required to be introduced into the body, otherwiſe it would be loſt; when it is not to be uſed immediately, the neck of the bladder may be tied with a ſtring, and thus may be kept for any required time.

Conſidering the medical properties of fixed air, it appears very remarkable, that this fluid, ſo noxious for the breath and lungs of animals, ſhould be not only harmleſs, but ſalutary, when applied to other parts of the body. Some perſons have ſuſpected, that to introduce this elaſtic fluid into the body, may occaſion diſtenſion, flatulencies,

cies, &c. but here it muſt be conſidered, that fixed air is eaſily abſorbed by the fluids of the body, and therefore as ſoon as it is introduced it incorporates with thoſe fluids, and loſes its elaſtic form. Indeed I have heard ſome perſons, who have made uſe of it, ſay, that ſometimes it really occaſions a diſtenſion of the abdomen of the patient; but having often ſeen the inaccurate way that ſeveral of thoſe perſons had to get and adminiſter the fixed air, I can venture to ſay, that in general their fixed air was mixed with much common air, to which laſt fluid the diſtenſion of the abdomen ſhould be attributed; it being well known, that but a very ſmall quantity of common air is abſorbed by the fluids of the body, or by fluids in general.

The fixed gas in ſeveral caſes may be obtained in plenty, ſo as to impregnate water with it, and without having recourſe to the effervescing mixture of chalk and diluted vitriolic acid; for liquors undergoing the vinous fermentation emit a vaſt quantity of it, which, being heavier than common air, forms a conſiderable ſtratum upon their ſurfaces; and hence it is, that lighted candles brought near the ſurfaces of fermenting wines, beer, &c. are immediately put out; and that people who work in breweries, and have occaſion to be for a long time with their heads upon the fermenting ſubſtances, and breathe that air mixed with fixed air, are often deprived of their ſenſes, or nearly ſuffocated; which effect is often entirely attri-

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buted to the inebriating ſpirit of the liquor, namely, to that which occaſions drunkenneſs after exceſſive drinking. When cloſe cellars, in which great quantities of wine, or other liquors capable of fermentation, are kept ſhut for a conſiderable time, the accumulation of fixed air in them is ſuch, that on being opened, the candles that are brought down, are immediately extinguiſhed; and various caſes are related of people who have loſt their ſenſes, have dropped down, and even dead, on going down thoſe places. For this reaſon, the wine or beer cellars ſhould be always conſtructed ſo as to have a free ventilation, capable to expel the noxious elaſtic fluid that is generated from the liquors contained in them. When there is any ſuſpicion of the air of a cellar being infected, the beſt ſafety is to bring a lighted candle in the hand, which, by being extinguiſhed, will warn the people againſt breathing that air.

In breweries, upon the ſurface of the fermenting liquor in the vats, there is a ſtratum of fixed air about a foot deep, which, although it is continually mixing with the atmoſpherical air, yet is ſufficiently pure for many experiments. Thus, if a quantity of water be alternately poured from one veſſel into another, after the manner uſed to cool ſome liquors when they are very hot; and if this operation be performed within the ſtratum of fixed air, the water will ſoon become impregnated with it. "A "perſon," *ſays Dr.* PRIESTLEY, "who is quite a ſtranger to

" the properties of this kind of air, would be agreeably " amuſed with extinguiſhing lighted candles, or chips of " wood in it, as it lies upon the ſurface of the fermenting " liquor; for the ſmoke readily unites with this kind of " air, probably by means of the water which it contains; " ſo that very little or none of the ſmoke will eſcape " into the open air, which is incumbent upon it. It is " remarkable, that the upper ſurface of this ſmoke, float- " ing in the fixed air, is ſmooth, and well defined; whereas " the lower ſurface is exceedingly ragged, ſeveral parts " hanging down to a conſiderable diſtance within the body " of the fixed air, and ſometimes in the form of balls, " connected to the upper ſtratum by ſlender threads, as " if they were ſuſpended. The ſmoke is alſo apt to form " itſelf into broad flakes, parallel to the ſurface of the li- " quor, and at different diſtances from it, exactly like " clouds. Theſe appearances will ſometimes continue " above an hour, with very little variation. When this " fixed air is very ſtrong, the ſmoke of a ſmall quantity of " gun-powder fired in it will be wholly retained by it, no " part eſcaping into the common air.

" Making an agitation in this air, the ſurface of it " (which ſtill continues to be exactly defined) is thrown " into the form of waves, which it is very amuſing to look " upon; and if, by this agitation, any of the fixed air be " thrown over the ſide of the veſſel, the ſmoke, which is " mixed with it, will fall to the ground, as if it was ſo "much water, the fixed air being heavier than common "air *".

EXPERIMENT II.

To produce inflammable Air.

The proceſs for making this ſort of gas is the ſame as that for making fixed air, deſcribed in the preceding experiment; one of the materials only muſt be different, viz. iron filings, or groſsly-powdered zinc, muſt be uſed inſtead of chalk; to which filings ſome oil of vitriol and water muſt be added, in the ſame proportion as in the preceding experiment, or rather a little more of oil of vitriol.

N. B. Inſtead of the filings of iron, ſmall nails, or ſmall bits of iron wire, anſwer equally well.

The inflammable elaſtic fluid produced by this mixture, has a diſpleaſing ſmell, even when mixed with a very large quantity of common air; ſo that if any conſiderable quantity of it comes out of the bottle, before the cork with the bent tube be applied to it, &c. its ſmell may be perceived all over the room in which the experiment is made; but this ſmell is not particularly offenſive.

When a bottle has been filled with this elaſtic fluid, ſtop the mouth of it with your thumb, or any ſtopper, and taking it out of the baſin, bring it near the flame of a candle, and when the mouth of the bottle is very near it, remove the ſtopper, and the elaſtic fluid contained in the bottle will be immediately inflamed; and, if the capacity of the bottle is nearly equal to four ounces meaſure, it will continue burning quietly for about half a minute, the flame gradually deſcending lower and lower, as far as about the middle of the bottle, in proportion as the inflammable gas is conſumed.

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* PRIESTLEY on different kinds of air, Part I. Sect. 1.

In this experiment we ſee, that inflammable air follows the general rule of all other combuſtible ſubſtances, namely, that of burning only when in contact with common air; thus the flame of this gas, whilſt burning, is obſervable only on that ſurface of it, which is contiguous to the common air, ſo that if the bottle be cloſed, the flame is put out immediately, becauſe the air is intercepted from it. But if the inflammable air were put in ſuch a ſituation as to expoſe a very great ſurface to the common air, it is plain, that by this means its combuſtion would be accelerated, ſo as to let it burn inſtantly, and go off with an exploſion, cauſed by the ſudden rarefaction of the air. In fact, this effect may be eaſily obſerved in the following manner:—When the bottle is to be inverted into the baſin, in order to let it be filled with the inflammable gas, inſtead of filling it entirely with water, let half of it remain filled with common air; then invert it, and let the other half, which now is filled with water, be filled with inflammable air after the uſual manner, and when the bottle is full, remove it in the manner ſhewn above, and approach it to the flame of the candle, by which means the inflammable air takes fire; but now it explodes all at once with a large flame and a conſiderable report, ſometimes breaking the bottle in which it is contained. In this caſe, the bottle being filled with equal parts of inflammable and common air, theſe two elaſtic fluids were mixed together, ſo that almoſt every particle of the one touched every particle of the other, and hence the ſudden combuſtion was occaſioned. The force of this exploſion is ſo very conſiderable, that ſome piſtols have been contrived, which are charged with a mixture of air and inflammable gas, and being fired by means of an electric ſpark, are capable to drive a leaden bullet with great violence. Sometimes thoſe piſtols are made of glaſs (but in this caſe they are not charged with a bullet) and it is very diverting to ſhew, that piſtols are charged and explode by the combuſtion of an inviſible ſubſtance.

When a ſlender pipe is tied to the neck of a bladder, and the bladder is filled with inflammable air, after the manner deſcribed in the preceding experiment (viz. when the bladder was required to be filled with fixed air) two very pleaſing experiments may be performed with it. Firſt, the inflammable gas may be inflamed by applying the flame of the candle to the extremity of the pipe; and ſqueezing at the ſame time the bladder, a ſtream of fire will be formed in the air, which will laſt as long as the bladder contains any inflammable air; for this gas coming out of the pipe with violence, will continue inflamed for a conſiderable way in the air. Secondly, the extremity of the pipe may be dipped into a ſolution of ſoap, then removing it from the ſolution, and ſqueezing the bladder very gently, a ball of ſoap-water may be formed, including inflammable air; which ball, on account of the inflammable gas being much lighter than common air, as ſoon as it is detached from the pipe, will aſcend upwards, and will break by daſhing againſt the ceiling, contrary to thoſe commonly made by children, which in ſtill air go downwards.—Whilſt the ball is aſcending, if the flame of the candle be approached to it, the film of ſoap-water will be inſtantly broke, and the inflammable air will take fire; thus a flame may be ſhewn to be ſeemingly produced from a ſoap-ball.

When a bottle, or any other receiver, filled with this or any other noxious elaſtic fluid, is inverted in water or mercury, an animal being introduced in it, will be inſtantly affected with convulſions, and will be deprived of life; but, except it is for the ſake of aſcertaining ſome new fact, diverting experiments in general ſhould be rather made with inanimate things, than with the lives of animals, and at the expence of humanity.

EXPERIMENT III.

To make nitrous Air.

The materials for making nitrous air, are bits or filings of copper or braſs, and diluted nitrous acid. The metal is firſt put into the bottle (which, as well as the whole proceſs, is the ſame as that deſcribed in the firſt experiment) ſo as to fill about one third of the ſame, then ſome water is poured into the bottle, ſo as juſt to cover the metal filings, and laſtly the nitrous acid is added, the quantity of which, when ſtrong, ſhould be about one third, or half the quantity of the water. The ſmell of the nitrous gas is very penetrating and offenſive, and, as was obſerved above, it occaſions a red ſmoke as ſoon as it comes into contact with the common air: hence, whenever any of it eſcapes from the bottle, it may be obſerved, not only by the ſmell, but alſo by the ſlight red colour.

In order to obſerve the principal property of this elaſtic fluid, which is that of diminiſhing the bulk of common air, let a glaſs tube, cloſed at one end, and about nine inches long, and half or three quarters of an inch in diameter, be filled with water, and inverted in water; then take a ſmall vial, of about half an ounce meaſure, filled with common air, and plunging it under the water contained in the ſame baſin where the inverted tube is kept, let that quantity of air enter into the tube[*], which will go to the top of it, the water ſubſiding accordingly. Let a mark be made, either with a file, or by ſticking ſoft wax on the tube, juſt oppoſite to the ſurface of the water in it, which will mark how much of the tube is filled by that given meaſure of air. After the ſame manner, fill the ſame ſmall vial (which we ſhall call the *meaſure)* again with air; throw that air into the tube, and put a mark on the tube, coinciding with the level of the water in it. In this manner let four or five meaſures be marked on the tube. Now if three meaſures of common air are put into this tube, when filled with water and inverted, they will fill a ſpace of it as far as the third mark. The ſame thing will happen if three meaſures of nitrous, inſtead of common air, are put in it; but if two meaſures of common air, and one meaſure of nitrous air, or one meaſure of the former, and two of the latter, are introduced in it, they will fill a ſpace much ſhorter than the third mark. On the moment that theſe two kinds of elaſtic fluids come into contact, a reddiſh appearance is perceived, which ſoon vaniſhes, and the water, which at firſt nearly reaches the third mark, riſes gradually into the tube, and becomes nearly ſtationary after about two or three minutes; which ſhews that the diminution is effected gradually.

If a given quantity, for inſtance, one meaſure of fixed air, and another meaſure of nitrous air, are introduced into the meaſured tube, no diminution will take place; neither if inflammable air and nitrous air are mixed together: in ſhort, the diminution will take place only when reſpirable air is mixed with nitrous gas, and it is greater when the air is purer, and contrarywiſe: hence this method is uſed to try the purity of the air; comparing the air of one time or place with that of another; but for ſuch purpoſe the meaſures on the tube muſt be ſub-divided into parts, as for inſtance, 20, 30, or other number of parts of a meaſure, which is uſually done by dividing the length between two marks with a pair of compaſſes, and marking thoſe diviſions either upon the tube, or upon a braſs ſcale to be applied occaſionally againſt the tube; for the ſmalleſt differences muſt be accurately remarked in ſuch caſes.

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[*] See the 208th page of this work.

A tube ſo divided, or in general an inſtrument conſtructed for the purpoſe of obſerving the purity of the air, ſhewn by the diminution of its bulk when mixed with nitrous air, has been called an *eudiometer*. This inſtrument has been contrived and deſcribed of various forms, each of which has its peculiar faults and advantages, as will be obſerved in the ſequel.

There is another property of nitrous air, that may be eaſily tried by the ingenious reader. This is its power of preſerving ſeveral bodies, eſpecially animal ſubſtances, from putrefaction for a very long time. Pigeons, pieces of meat, and the like, have been preſerved wholeſome and untainted for many weeks, by being only kept in a jar containing nitrous air. When a bottle, or any receiver, inverted in water, is filled with nitrous air, a piece of meat may be introduced in it by paſſing it through the water; but when it is within the receiver, it ſhould be kept ſo as not to touch the water, which may be eaſily done by means of ſticks, or any thing that may ſerve as a ſtool. A receiver, with a hook proceeding from the top of it, may be eaſily conſtructed for this purpoſe. After ſome days or weeks this meat may be taken out, and, being waſhed and dreſſed, it will be found to be wholeſome, and without the leaſt mark of putridity. It may only be obſerved, that when it has been kept for a very long time, it loſes its natural taſte and flavour, and becomes rather inſipid or unpleaſant to the palate.

Notwithſtanding the great power of this elaſtic fluid to preſerve animal ſubſtances from putrefaction, I do not find that nitrous air was ever uſed in medicine with any good effect; and it ſeems, on many accounts, improbable that its uſe ſhould be attended with any.

EXPERIMENT IV.

To make dephlogiſticated Air.

The eaſieſt method to procure ſome dephlogiſticated air, is to put ſome red-lead into the bottle, together with ſome good ſtrong oil of vitriol, but without any water. Let the red-lead fill about a quarter of the bottle, and the vitriolic acid be about the ſame quantity, or very little leſs; then apply the bent tube to the bottle, and proceed in the ſame manner as above.—But it muſt be remarked, that without heat this mixture of red-lead and vitriolic acid will not give any dephlogiſticated air, or it yields an inconſiderable quantity of it, for which reaſon the flame of a candle (that of a wax taper is ſufficient) muſt be applied under the bottom of the bottle, which for this purpoſe muſt be rather thin, otherwiſe it will be eaſily cracked*. In this manner the red-lead will yield a good quantity of elaſtic fluid, the greateſt part of which is dephlogiſticated air, but not the whole quantity of it, for a good portion of fixed air comes out with it. In order to ſeparate the fixed from the dephlogiſticated air, the inverted bottle, when filled with the compound of both, as it is emitted from the read-lead, muſt be ſhook in the baſin, after the manner ſhewn in the firſt experiment, for impregnating water with fixed air; by which means the water will abſorb the whole quantity of fixed air, and leave the dephlogiſticated air by itſelf.

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* In this operation, the flame of the candle, when once applied, muſt be kept continually near it; and when the mixture does not produce any more elaſtic fluid, or the operation is required to be intermitted, care ſhould be taken to remove the extremity of the bent tube from the water *firſt*, and then to take off the flame of the candle from under the bottle; otherwiſe, if the flame of the candle be firſt removed, the materials within the bottle condenſing by cold, the water immediately enters, which in an inſtant fills the bottle, and generally breaks it.

When a bottle is thus intirely, or in good part, filled with dephlogiſticated air, ſtop it with your thumb, or any ſtopper; take it out of the water of the baſin; turn it with the mouth upwards; then light a bit of wax taper, faſtened to the extremity of a wire, in the manner ſhewn in fig. 19, and removing the ſtopper from the bottle, let the lighted taper down into it, and it will be found that as ſoon as it comes into contact with the dephlogiſticated air, its flame is increaſed to a prodigious degree. It burns with a kind of violence or deflagration, and an increaſed light, that is very beautiful to behold: but in proportion as the dephlogiſticated air becomes contaminated, the flame gradually leſſens, and at laſt is extinguiſhed, in the ſame manner as if it were put into common air. Chips of wood, with only a red coal at their extremities, when let down into a jar containing dephlogiſticated air, will inſtantly flame, and burn very rapidly, till the dephlogiſticated air becomes contaminated.

If a quantity of inflammable be mixed with an equal quantity of dephlogiſticated air, and the mixture be fired, the exploſion is incomparably greater, than if common air had been mixed with the inflammable gas.

By placing an animal in a receiver filled with this elaſtic fluid, and another like animal in an equal receiver filled with common air, it will be found that the former will live much longer than the latter ; all which clearly ſhews, that this ſort of elaſtic fluid, called dephlogiſticated air, is much more fit to aſſiſt reſpiration and combuſtion than common air is ; and accordingly, if a meaſure of it, with a meaſure of nitrous air, be put into an eudiometer, (viz. into the above-mentioned meaſured tube) the diminution will be found to be much more conſiderable than if a meaſure of common air, and another meaſure of nitrous air, were mixed together.

EXPERIMENT V.

To make nitrous acid Air.

Hitherto we have deſcribed the methods of obtaining ſuch elaſtic fluids as are not, or but ſlowly, abſorbed by water ; and the reader may recollect, that beſides the difference of materials, and the neceſſity of applying heat for the production of the laſt-mentioned elaſtic fluid, the reſt of the operation, and the inſtruments neceſſary, are the ſame in each proceſs. Indeed, they are the ſame in the following alſo; but as the other elaſtic fluids are inſtantly, and in great quantity, abſorbed by water, ſome other fluid muſt be ſubſtituted inſtead of water ; and the beſt fluid hitherto found, is quickſilver, with which the baſin and the inverted bottle muſt be filled. The price and weight of this moſt uſeful fluid are certainly ſuch as will render its uſe much leſs common than water; but there is no other remedy, beſides that of uſing as ſmall a baſin and receiver as may be juſt ſufficient for the purpoſe, and to take care to loſe the ſmalleſt poſſible quantity of mercury; for by the various operations of removing and replacing inſtruments, &c. ſome mercury is always dropped, even by the moſt experienced perſons.

In order to obtain the vitriolic acid air, ſome ſtrong concentrated vitriolic acid muſt be put into the uſual bottle, together with ſome ſubſtance capable of furniſhing phlogiſton. Olive oil anſwers very well. The oil of vitriol ſhould be about three or four times as much as the ſweet oil, and both together ſhould fill about one third or half the bottle. A gentle degree of heat is then required, in order to let theſe materials yield any elaſtic fluid; which may be done by applying the flame of a wax taper, as directed above for the production of dephlogiſticated air.

This elaſtic fluid has no action upon quickſilver, but is eaſily, and in great quantity, abſorbed by water; ſo that if a ſmall quantity of water be introduced into the receiver containing it, and inverted in quickſilver *, the whole

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* In order to introduce water, or any other fluid, into a receiver inverted in quickſilver, let a ſmall phial be quite filled with that liquid, then holding it with the hand, ſtop its mouth with a finger, and thus plunge it into the quickſilver, and paſs it under the inverted receiver, where being unſtopped, and turned with the mouth upwards, the contained fluid will inſtantly aſcend to the top of the quickſilver in the receiver, on account of its being ſpecifically lighter than quickſilver.

quantity of the acid air diſappears, being abſorbed by the water; from which it eſcapes very eaſily when expoſed to the open air. The water thus impregnated acquires the properties of the volatile or ſulphurous vitriolic acid.

A piece of camphor introduced into a receiver containing this kind of elaſtic fluid, is eaſily diſſolved, but by the addition of water the camphor is again recovered.

If a piece of charcoal is admitted to this vitriolic acid gas, it abſorbs a good quantity of it, and acquires from it a diſagreeable and pungent ſmell. It is remarkable, that this elaſtic fluid does not act upon iron; whereas the water combined with it is a powerful ſolvent of that metal.

EXPERIMENT VI.

To make marine acid Air.

Put ſome ſea-ſalt, or common kitchen ſalt, into the uſual bottle in which the materials for producing elaſtic fluids are generally put, ſo as to fill about a fourth part of it, and upon this ſalt pour a ſmall quantity of good concentrated vitriolic acid; then apply the bent tube to the bottle, and introduce it through the quickſilver into the receiver, filled with, and inverted in quickſilver, after the uſual method, and the elaſtic fluid, called *marine acid air*, is copiouſly produced.

A ſmall quantity of water introduced into a receiver, containing this ſort of elaſtic fluid, abſorbs inſtantaneouſly a prodigious quantity of it, and becomes a very ſtrong marine acid ſpirit; indeed, much ſtronger than can be obtained by any other means.

If any metallic, or, in general, any inflammable ſubſtance, capable of furniſhing a conſiderable quantity of phlogiſton, as ſpirit of wine, oil, &c. be introduced into a receiver filled with this elaſtic fluid, it occaſions a remarkable change, viz. the marine acid air, by acting on it, will be changed into an inflammable elaſtic fluid, that takes fire by the contact of ignited bodies.

When a ſmall quantity, as for inſtance, about a fourth part, of marine acid air is mixed with one part of common air, and a lighted candle is introduced into the receiver containing this mixture, the flame of the candle acquires a beautiful green or blueiſh colour.

EXPERIMENT VII.

To make nitrous acid Air.

The elaſtic fluid, called nitrous acid air, may be obtained from heated nitrous acid, the vapour of which acquires a permanent elaſticity, and it has been found to remain uncondenſed into a viſible fluid, by the cold to which it has been hitherto expoſed. The great difficulty, as we obſerved above, is to find a fluid capable of confining this acid air, becauſe it is eaſily and abundantly abſorbed by

water,

water, which is one of its properties by which it differs from nitrous air. It acts upon quickſilver, and alſo upon oils; hence its examination cannot be made but very imperfectly; for ſubſtances muſt be expoſed to it, or mixed with it, whilſt it is actually changing its nature by acting on the mercury or other fluid that confines it.

When water has abſorbed a good quantity of this elaſtic fluid, it acquires the properties of nitrous acid, and when heated, it yields a large quantity of nitrous air, viz. a quantity many times greater than that which water is wont to imbibe of it by agitation, or by any known means.

When the nitrous acid air is combined with eſſential oils, a conſiderable efferveſcence and heat is produced, nearly in the ſame manner as when the nitrous acid itſelf is poured upon thoſe oils.

EXPERIMENT VIII.

To make fluor acid Air.

Put ſome of thoſe minerals, called *fluors*, or *fuſible ſpars* *, pulverized, into the uſual bottle, and upon it pour ſome concentrated oil of vitriol; then adapt the bent tube, &c.—The fluor acid air is at firſt produced without the help of heat, but in a ſhort time it will be neceſſary to apply the flame of a candle to the bottle, by which means a conſiderable quantity of this elaſtic fluid is obtained.

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* See page 49 of this work.

The properties of fluor acid air are nearly the ſame as thoſe of the vitriolic acid air; hence ſome excellent philoſophers are of opinion, that thoſe two acid airs are eſſentially the ſame. The principal, if not the only property by which they are diſtinguiſhed from each other, is that when water is admitted into a receiver containing fluor acid air, the water abſorbs only a part of it; for a ſtony cruſt is formed upon the ſurface of the water, which hinders the farther abſorption, and which muſt be broke before the water abſorbs any more of it.

EXPERIMENT IX.

To make alkaline Air.

Let the uſual bottle be about half filled with volatile ſpirit of ſalt ammoniac, and after applying the bent tube, &c. let the flame of a candle be brought under the bottle, by which means the alkaline air will be produced copiouſly.

If a ſmall quantity of water is introduced into the receiver filled with this elaſtic fluid, the whole quantity of it is readily abſorbed by the water, which thereby becomes a ſtrong volatile alkaline ſpirit. If ſome of this gas is introduced into a receiver containing either the marine or the vitriolic acid air, a white cloud is inſtantly

formed,

formed, and the two inviſible elaſtic fluids, loſing at once their elaſticity, form a viſible ſubſtance, namely, concrete ammoniacal ſalts.

When alkaline air is mixed with common air, it becomes inflammable.

Thus, by thoſe few experiments, the reader may learn the eaſieſt methods of producing the various ſorts of permanently elaſtic fluids, without much expence, or great variety of inſtruments; and he may alſo know how to diſtinguiſh one ſort of elaſtic fluid from another, which is not only of uſe to thoſe perſons, who deſire to become acquainted with this branch of natural philoſophy, but alſo for thoſe who have a mind to divert a leiſure hour, or to aſcertain the exiſtence of different elaſtic fluids in various occaſions, as upon fermenting liquors, in the bottoms of pits, wells, &c.

In thoſe experiments I have purpoſely avoided to mention thoſe niceties of operations, which can never be expected from beginners, and the taking notice of which might have rather confuſed the reader. The properties of the various elaſtic fluids that have been mentioned, are alſo few; but they are the principal characteriſtics by which one may be diſtinguiſhed from the other, and which, after once or twice peruſing this chapter, may be eaſily remembered.

Suppoſe, for inſtance, that to a perſon who is acquainted with the characteriſtic properties of the different elaſtic fluids mentioned in this chapter, a receiver containing ſome elaſtic fluid, and inverted in water, was preſented, and that he was requeſted to find out what kind of elaſtic fluid that receiver contains. Firſt, it is plain, that this elaſtic fluid muſt be of thoſe that are not inſtantly abſorbed by water, otherwiſe it could not remain in the receiver inverted in water. Now, by inclining a little the receiver, ſo as to let a ſmall quantity of the contained elaſtic fluid out of it, and applying the noſtrils to it, he may eaſily diſtinguiſh whether that elaſtic fluid is nitrous, or inflammable air; for among thoſe that are not inſtantly abſorbed by water, theſe two elaſtic fluids only have peculiar ſtrong ſmells, which, when once known, can hardly ever be confuſed again. Secondly, if the elaſtic fluid contained in the receiver has no ſmell, it is plain, that it muſt be one of the reſt, viz. either common, or fixed, or dephlogiſticated air.—In this caſe, let a ſmall receiver be filled with part of the elaſtic fluid out of the large receiver, and being taken out of the water, turn it with the mouth upwards, and let a lighted wax taper down into it, which, if on its firſt reaching the bottom of this ſmall receiver, burns equally as well as it does in the open air, ſhews that the elaſtic fluid contained in the large receiver, out of which the ſmall one has been filled, is common air; if it burns much better than in the open air, viz. with an enlarged flame, a greater light, &c. it ſhews that the elaſtic fluid in queſtion is dephlogiſticated air; but if it is inſtantly extinguiſhed, then that elaſtic fluid muſt be either fixed air, or contaminated common air; but the former of thoſe two fluids is, by means of agitation, eaſily abſorbed by water, and the other is not; therefore, if a mark be put upon the receiver, coinciding with the ſurface of the water in it, and then the receiver be ſhook in water for about one minute (but taking care that none of the contained elaſtic fluid is let out of it) the queſtion will be immediately decided; for if a diminution is obſerved, which is indicated by the water riſing above the mark, the contained elaſtic fluid is fixed air; otherwiſe it is contaminated common air, or, as it is more uſually called, *phlogiſticated air.*

In a ſimilar manner the nature of the elaſtic fluid contained in a receiver inverted in quickſilver may be found out; for in the firſt place, by admitting a ſmall portion of water to it, may be eaſily known whether or no it is of thoſe which are inſtantly abſorbed by water. Secondly, If it is of thoſe that are abſorbed by water, its nature may be known by the taſte and ſmell it gives to the water, or by the ſtony cruſt it depoſits upon the ſurface of the water.

Here we have only ſuppoſed, that a ſingle elaſtic fluid is contained in the given receiver; but the difficulty conſiſts in finding out the different ſorts and quantities of permanently elaſtic fluids that are contained in a mixture of them, which is often required in performing experiments of this ſort; but this cannot be eaſily comprehended nor practiſed without a good acquaintance with the ſubject, and a readineſs in performing the experiments; we ſhall therefore take notice of it towards the latter end of this book.

CHAP. V.

Containing the deſcription and uſe of the apparatus principally neceſſary to make experiments relative to the nature and properties of permanently elaſtic fluids.

HITHERTO we have deſcribed thoſe few inſtruments, which are juſt ſufficient to initiate the novice in this ſubject, and to ſhew the principal characteriſtic properties of the different permanently elaſtic fluids; but a thorough examination of the various properties of thoſe fluids, and a farther inveſtigation of this ample field of philoſophical reſearches, requires a far greater number of inſtruments. Indeed, as this ſubject is connected with every branch of natural philoſophy, it requires the help of inſtruments belonging to other ſciences; for inſtance, the electrical machine, the chymical inſtruments, &c. are alſo neceſſary for it; but of thoſe we ſhall omit to give the particular deſcription, becauſe they are not immediately belonging to this ſubject, and they are fully deſcribed in various treatiſes written expreſsly on thoſe ſciences.

That the greateſt poſſible perſpicuity and diſtinction might be preſerved in the deſcription of the numerous inſtruments to be uſed in the experiments on air and other permanently elaſtic fluids, we ſhall arrange them into three claſſes, allotting to the firſt the inſtruments neceſſary to detain the various elaſtic fluids; deſcribing in the ſecond thoſe neceſſary for their production; and in the laſt, mentioning thoſe inſtruments which are neceſſary to ſhew the divers properties of thoſe fluids, and to employ them for the various intereſting purpoſes of philoſophy, phyſic, and œconomy.

Here the reader muſt remark, that this apparatus is intended for thoſe who are not yet provided with any; in which caſe it is neceſſary to give the moſt uſeful directions, that the preſent knowledge of the ſubject can furniſh; but for thoſe who are already furniſhed with inſtruments of this ſort, it is not adviſeable to have them altered for the ſake of following the directions given in this chapter, excepting, however, thoſe conſtructions were attended with remarkable inconveniences.

The principal inſtruments that are neceſſary, to make experiments on air and other permanently elaſtic fluids, are, a tub filled with water, and another filled with mercury. Fig. 1. plate II. repreſents the tub to be filled with water. The ſize and ſhape of this tub has been varied according to the fancy of almoſt every perſon, who has made uſe of it, and according as new diſcoveries have, from time to time, pointed out ſome advantages or defects of particular conſtructions. When a perſon has the advantage of a pipe that conveys abundance of water into his experimental room, he may uſe as large a tub as he pleaſes; it being a great advantage to uſe a very large veſſel, wherein many or one long ſhelf may be fixed, ſo as to contain ſeveral receivers, and to admit of many operations being carried on at once; but for the generality of perſons, ſuch very large tub would be inconvenient, on account of the trouble that attends the changing its water, which, when experiments are frequently performed, ſhould be changed at leaſt once a week.

The tub A B C D, repreſented in fig. 1, is ſuch as may be uſeful for every experiment that can be performed in water. It is of an elliptical or oval ſhape; its longeſt axis, viz. from A to B, being about 28 inches, and the ſhorter, viz. its breadth, being about 14 inches. Its depth is 17 inches. The wood of which the tub is to be made, ſhould be compact, ſtrong, and rather old. The finer ſort of mahogany is very good for this purpoſe; but this wood is much dearer than that commonly employed for waſhing-tubs. This laſt-mentioned ſort of wood generally gives ſome colour to the water; but when the tub made

of

of it has been kept full for ſome time, and the water has been changed five or ſix times, it no longer imparts any colour or taſte to the water. The beſt and cheapeſt way is to have a tub of this ſort of wood, hooped with iron hoops, and painted on the outſide with ſome oil paint, which will preſerve both the wood and the iron hoops. Two braſs or iron handles, K K, ſhould be fixed on the outſide of this tub, which are very uſeful when the veſſel is required to be emptied, or carried from one place to another. Some perſons chuſe to have the inſide of the tub painted, or lined with lead; but my reader may reſt aſſured, that the naked wood is by far the more preferable, becauſe, after having performed ſome experiments, the water of the tub becomes impregnated with acids, with elaſtic fluids, and other ſubſtances, which corrode that lining, and render ambiguous the experiments that are performed in the tub. Perhaps a very thick coat of ſtrong copal varniſh would not be amiſs; but this coat of varniſh is expenſive, requires a long time to dry, and is ſubject to crack. The beſt thing would be, to uſe a veſſel of hard earthen ware, made in the ſhape of the veſſel A B C D, with a ſhelf, and all of one piece; but I am confident, that the price, and facility of breaking ſuch a veſſel, will prevent its uſe to become general.

On one end of this tub an horizontal ſhelf *e g f*, is to be fixed, about 3 inches below the edge of the tub, and ſo long as to come within a little more than the third part of the length A B of the tub. The ſhelf muſt be made with one piece of wood, about one inch and a half, or two inches thick, and on the under ſide of it two funnels muſt be excavated into the thickneſs of the wood, and terminating in the holes *h i*; which holes are a little more than a quarter of an inch in diameter, and lie about one inch diſtance from the edge *e f*.

Fig. the 2d, plate II. repreſents the under ſide of the ſhelf, with the funnels, and alſo a cut of the ſame through the line A B; which is done in order to give a better idea of the ſhape of thoſe funnels.

Fig. the 3d, plate II. repreſents the inſide of the extremity A C *e f* of the tub, which ſerves to ſhew the manner of faſtening the ſhelf in it, viz. by fixing it in the groove made by the ſmall pieces of wood L L L M M M, which are nailed to the tub. When the ſhelf is to be taken out, in order to clean the tub, it is plain that it muſt be taken off by pulling it horizontally towards the end B, fig. 1, of the tub; and as it might ſometimes come out of its place when it is not required, a peg is thruſted in a ſmall hole at *e* in the tub, which will effectually prevent its coming out. The beſt ſituation of this tub is upon a ſtool, ſo high that its edge may be about thirty inches above the floor, which is a very convenient height for perſons, who chuſe to ſit when they make experiments near it; but if any body had rather ſtand, then the tub muſt be placed higher. In any caſe, it ſhould be always ſituated near a window;

it being neceſſary to have a good light falling upon it, and the operator ſhould never place himſelf between the tub and the window. To ſituate it againſt a wall, as ſome people do, is rather inconvenient.

The tub for the quickſilver, which is neceſſary for experiments upon thoſe elaſtic fluids which are eaſily abſorbed by water, is a wooden box, A B C, fig. 4, plate II. of an oblong form. The larger this box is made, the more uſeful it is; but the price and weight of the quickſilver is ſuch, that obliges one to adopt the ſmalleſt ſize that can be juſt ſufficient. Several perſons uſed to fill a common baſin with quickſilver; but ſuch veſſels are very inconvenient, firſt, becauſe their ſhape is not the beſt calculated to render uſeful a ſmall quantity of quickſilver; and ſecondly, becauſe a ſhelf cannot be conveniently fixed in them.

The box A B C ſhould be at leaſt 12 inches long, 4 inches wide, and 5 inches deep; which, when filled with quickſilver till within about half an inch of the top or edge, contains about 100 pounds weight of quickſilver. A veſſel of ſmaller dimenſions may be adapted to ſeveral experiments, but in general is very inconvenient to operate in. To one end of the box or trough A B C a ſhelf muſt be fixed, made of a piece of wood about half an inch thick, having a funnel excavated in its under part, and terminating in the hole *f*. The ſhelf ſhould be fixed in grooves, after the manner deſcribed above for the water-tub; ſo as to admit the ſhelf being eaſily taken out and replaced again. Fig. 5, plate II. repreſents the ſhelf inverted, and alſo a cut of the ſame along the line R R. The hole *f*, fig. 4, muſt not be even with the ſhelf, but ſhould terminate in a ſmall pipe about a quarter of an inch high, as may be clearly ſeen in the cut of the ſhelf, fig. 5. This may be done by gluing in the hole a turned piece of wood or ivory, with a hole through, of about a quarter of an inch in diameter; but this piece on the under part of the ſhelf ſhould be filed, and made to go even with the ſide of the funnel, ſo that no edge may remain; which, in performing the experiments, would hinder and retain ſome of the elaſtic fluid that is intended to be ſent through.

This box A B C ſhould be furniſhed with two iron or wooden handles, like that ſeen in the figure at L, and ſhould be ſituated within another ſhallow and much larger box H I K, which ſerves to retain any quickſilver that is dropped out of the box A B C, as is generally the caſe.

The trough H I K may be made about 18 inches long, 10 wide, and 2 deep.

This mercurial trough may be ſituated as high as the water-tub, or according as it may be more convenient to the operator.

Fig. the 6th, repreſents the various ſorts of glaſs receivers neceſſary to retain the different ſorts of elaſtic fluids. The operator ſhould have many of thoſe receivers by him, as they are the inſtruments of more general uſe in this branch of experimental philoſophy. Their ſhapes may be reduced to two ſorts, viz. rounded, and furniſhed with a knob at top, like A, of which form the large receivers are uſually made; and the cylindrical ones, like B, C, D, E. Thoſe of the firſt ſort are between 9 and 15 inches high, and with an opening between 6 and 10 inches in diameter. Thoſe of the ſecond ſort are of a great many ſizes, and ſome of them are ſo ſmall that their diameter is about a quarter of an inch, and their height a few inches. Thoſe between one and two inches in diameter, and five or ſix inches high, are the moſt uſeful for experiments in quickſilver. The operator ſhould have by him four or ſix receivers of the firſt ſort, and between one and two dozen of the ſecond; comprehending various ſizes from the largeſt to the ſmalleſt. Care ſhould be had to chuſe very ſtrong receivers, and thoſe of the ſecond ſort to be as perfectly cylindrical as can be poſſibly found, becauſe it is often required to meaſure the quantity of elaſtic fluid they contain, which cannot be done very accurately, when the cavities of thoſe receivers are of an irregular figure. Beſides the receiver, bottles with ground glaſs ſtopples, and bladders, are not only uſeful, but in various caſes are abſolutely neceſſary, to keep ſome ſorts of elaſtic fluid, viz. in caſe it is required to preſerve them without the contact of water, mercury, or any other fluid; and alſo when elaſtic fluids are required to be tranſported from one place to another. In the choice of bottles with glaſs ſtopples, care ſhould be taken to have them rather with large mouths, in order that they may be eaſily cleaned when neceſſary; and alſo that their ſtopples be well fitted; for often they are ſo badly ground, that various ſubſtances can eaſily get through the interſtices left between the ſtopper and the neck of the bottle, which renders them uſeleſs for nice experiments.

As it is neceſſary to remove from the water-tub, or from that with quickſilver, ſome receivers filled with elaſtic fluids, many ſhallow earthen pans, of different ſizes, like A and B, fig. 7, plate II. ſhould be had ready at hand; for when the receiver, that is to be moved, ſtands upon the ſhelf of the tub, one of theſe pans, that is ſomewhat larger than the aperture of the receiver, is plunged into the water of the tub, and the receiver is drawn in it, but without lifting it above the ſurface of the water, and then it may be removed, and placed together with the pan upon a table, without fear that any of the contained elaſtic fluid might eſcape, or any air might enter; becauſe the ſmall quantity of water which fills the pan, is ſufficient to prevent it. For ſmall receivers, when they are to be removed from the trough of quickſilver, ſmall cups, like C, fig. 7, may be uſed.

When one or more tall and ſlender tubes are to be kept inverted in a baſin or pan, as their baſis is very ſmall, they are ſubject to fall, and conſequently they may not only loſe the contents, but may alſo break. To obviate this inconvenience, it is very uſeful to have a wooden ſort of ſkreen or frame, made like fig. the 8th, plate II. in the bottom of which the baſin with quickſilver or water may be placed, and againſt whoſe ſides and corners the tubes or ſmall receivers are reſted.

The inſtruments of the ſecond claſs are thoſe neceſſary for the production of the different permanently elaſtic fluids. They chiefly conſiſt of glaſs bottles with bent tubes, which are nicely ground into their necks. See thoſe repreſented in fig. the 9th. plate II. A is the ſimpleſt and moſt uſeful ſort; its capacity being of about four ounces meaſure, and the bottom being round and moderately thin, ſo as to admit of the flame of a candle being applied under it, without much fear of cracking it. B is of the ſame ſhape, only ſomewhat longer. C has two necks, viz. one into which the bent tube is fitted, and another having a glaſs ſtopple, which is occaſionally removed, and then ſomething may be introduced into the phial whilſt the proceſs is going on. E has a ſtraight tube, whoſe extremities only are bent, nearly at right angles. This phial is uſeful when the receiver, wherein the produced elaſtic fluid is to be introduced, is far from that part of the edge of the tub where the phial with the effervеſcing mixture, &c. may be conveniently ſituated. D is a common glaſs bottle with a ground glaſs ſtopple, through which many capillary holes are perforated. Sometimes the bent glaſs tube may be applied to the phial by means of a cork, as deſcribed in the firſt experiment of the preceding chapter; but in general the phials, whoſe tube is ground into their necks, are by far the more preferable, becauſe the cork is ſubject to be corroded by the acids employed, and beſides, the tubes can ſeldom be fitted in them ſo nicely as effectually to exclude the paſſage of any elaſtic fluid.

The bottles of elaſtic gum, or *caſutchouc*, are exceedingly uſeful for experiments of this ſort. They anſwer both the purpoſe of retaining elaſtic fluids, like bladders or receivers, for which uſe they are preferable to bladders; and of holding the materials which muſt produce the elaſtic fluids, but only when no heat is required for the proceſs. Any bent tube may be eaſily applied to them, and there is no fear of their breaking, like glaſs bottles. When concentrated nitrous acid has been put many repeated times into thoſe bottles of elaſtic gum, they loſe in part their elaſticity, ſo that the inſide becomes brittle, as if partly corroded, and then they are eaſily broke; however they may be uſed for a long time before they come to that ſtate; but vitriolic acid, which is uſed in the common proceſſes for making fixed and inflammable air, ſeems not to affect them. When theſe bottles are required to be uſed inſtead of bladders, they ſhould be as large as may be got, and ſhould be rather thin, ſo as to be eaſily compreſſed, in order to expel from them the common air they contain, previous to their being filled with any particular ſort of permanently elaſtic fluid.

Theſe are the phials more commonly uſed, when the elaſtic fluid that is extricated from ſeveral ſubſtances is required to paſs immediately into the receiver inverted in water or quickſilver; but ſometimes it is neceſſary to let thoſe elaſtic fluids paſs through ſome other particular fluid or mixture previous to their entering into the inverted receiver. In this caſe the glaſs inſtruments K and L muſt be uſed. The conſtruction of K may be clearly underſtood by inſpecting the figure: it conſiſts of a phial *a*, with a round bottom, into which the materials that muſt yield the elaſtic fluid are put. To the neck of this phial a tube is fitted, whoſe other leg fits a hole made at the bottom of the phial *b*, and its extremity *e* comes as far as the neck of the phial, but not quite ſo near as to touch it.—The phial *b* has a glaſs ſtopple ground into its neck, and at the bottom has another hole, into which a bent tube, like thoſe of the phials A, B, C, is fitted. Now when the elaſtic fluid, that is yielded by the materials in *a*, muſt be let through ſome fluid or mixture, as for inſtance through lime-water, previous to its being received into the inverted receiver or bladder; the lime-water is put into the phial *b*, ſo as to fill it to about *c d*; in which caſe it is plain, that the elaſtic fluid coming out of the orifice *e* of the tube, muſt neceſſarily go through the lime-water before its reaching the tube *f*, through which it is conveyed into the receiver. The inſtrument *h* is uſeful when the elaſtic fluid is required to be ſent through various fluids or mixtures, as for inſtance, through lime-water, ſpirit of wine, oil, &c.; which fluids are put into the various phials *b*, *c*, *d*; and then the elaſtic fluid produced by the materials in *a*, muſt paſs through them all before its going through the laſt tube *e* into the receiver.

In various experiments, the materials which are to yield the elaſtic fluid, require a ſtronger degree of heat than that of the flame of a candle. In this caſe ſeveral things muſt be minded, viz. that by the application of ſtrong heat, as a charcoal fire, the phials are eaſily broke; that part of the materials ſtick faſt to the glaſs, ſo as to render the phial unfit for farther uſe; and that the tube becomes very hot, even at a good diſtance from the phial, and as its extremity is immerſed in cold water, it is in great danger of breaking: from which obſervations it follows, that the phials for theſe experiments ſhould be as cheap as can be poſſibly contrived, and ſhould have a very long neck or tube. The bottles with ground tubes for thoſe experiments are very ſubject to break, and are very expenſive. Mr. FONTANA uſed to have ſeveral balls blown at the extremities of glaſs tubes, as F, G, which were of various ſizes, between one and four inches in diameter; and alſo ſeveral tubes bent in the manner repreſented by I. Into one of thoſe glaſs balls he uſed to put the materials that were to yield the elaſtic fluid, and by means of the flame of a lamp, and a blow-pipe, he uſed to faſten the tube I upon it, viz. *a* upon *b*, which all together formed the long-necked phial H. After performing the experiment, if the phial appeared to be uſeful for other experiments, the tube was broke with a file, about the place where it had been joined, and the materials being poured out, the phial was kept for farther uſe. Sometimes the balls of thoſe phials were coated with clay, or that lute which chymiſts uſe to put round their glaſs retorts. This coat is neceſſary, in order to let the glaſs ſuſtain a greater degree of heat than it is capable of without it.

Several experiments require a very ſtrong red or white heat, which is much greater than that which the above-mentioned phials can bear, even when guarded with a coat of clay. In this caſe earthen retorts, or earthen phials, are the only veſſels that can be uſed; but theſe cannot be ſafely uſed more than once, becauſe in cooling they generally crack, and the fiſſures are ſometimes imperceptible. Small phials, made of tobacco-pipe clay, do not crack very eaſily in cooling, and conſequently are more uſeful than thoſe made with the clay uſed for common chymical retorts.

Various perſons have uſed retorts of caſt iron, or the barrel of a gun; but theſe cannot be ſafely uſed for nice experiments, becauſe heated iron emits ſome inflammable air or phlogiſton, which renders ambiguous the reſult of the experiments. When an earthen retort is uſed, the bent glaſs tube is faſtened into its neck with common clay or lute; and if the neck of the retort is pretty long, may alſo be faſtened by only wrapping and tying a piece of bladder round the joint. When the materials to be uſed are in ſmall quantity, and require only a ſtrong red heat, then Mr. BERGMAN's method may be ſafely uſed. This excellent chymiſt uſes to put the materials into a ſmall and oblong phial, nearly in the ſhape of B, fig. 9, of green glaſs *, which phial is furniſhed with a bent tube, &c. This phial he puts into a tall crucible, and fills the interſtices between the crucible and the phial with powdered chalk, which, when heated, forms a ſtrong incruſtation, and defends the glaſs exceedingly well. Thus the crucible with the phial in it is ſurrounded with coals, in a portable furnace, and may ſuſtain a ſtrong fire.—Could platina be ſhaped into any required form, a retort or a phial of this metal would be a very valuable acquiſition to an experimental philoſopher, becauſe it could ſuſtain a prodigious heat, and would not be ſubject to break, like glaſs or earthen retorts, or to yield any effluvia, like heated iron.

The ſtand, fig. 10, is uſeful to ſuſtain a lamp under a phial, like A, B, C, fig. 9, in order to let its contents yield the elaſtic fluid. The arm A, which holds the lamp, is made like a pair of tongs, which are opened more or leſs by means of a ſcrew, and it ſlides up and down the pil-

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* Green glaſs ſuſtains a greater degree of heat than tranſparent colourleſs glaſs.

lar B C, ſo that by the ſcrew D may be faſtened at any required diſtance between C and D from the floor *.

The ſtand repreſented in fig. 11, has two arms, and ſometimes they are made with more, which are faſtened at any required diſtance, like that above deſcribed. Upon the extremities of thoſe arms, a phial, a lamp, a ſmall pan with charcoal, or any thing of the like ſort, may be placed, according as occaſion may require.

Fig. the 13th, repreſents a ſmall glaſs funnel, which ſometimes is uſeful to tranſmit any elaſtic fluid from one veſſel into another. The diameter of the ſmalleſt part of this funnel ſhould be not leſs than a quarter of an inch, otherwiſe the air, or any other permanently elaſtic fluid, will paſs ſlowly and with difficulty through it. As a funnel of glaſs is ſpecifically heavier than water, when it is uſed, it muſt be kept with the hand or otherwiſe againſt the upper veſſel, viz. that into which the elaſtic fluid muſt be introduced; and as this holding, &c. is generally incommodious, I have moſtly uſed a funnel of wood, whoſe larger part is about three inches in diameter, which being lighter than water, will by itſelf reſt againſt the upper veſſel in water, without the neceſſity of holding it. For experiments in quickſilver the glaſs funnel is very uſeful, but for that purpoſe it muſt be made very ſtrong.

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* Inſtead of oil, ſpirit of wine ſhould be put into the lamp here mentioned, becauſe when oil is uſed, the bottoms of the phials are blackened by the ſmoke; which is not the caſe with a ſpirit-lamp.

Fig. the 12th, repreſents the ſhape of the phials, in which acids or other liquors are to be kept.—It may be thought hardly neceſſary to give a delineation of this ſort of phials; but as there is often a great convenience in little things, it may be of uſe to mention that phials, with a beak like that delineated in the figure, and a ground ſtopple, are much preferable to thoſe with a round neck, becauſe in pouring out the liquor, the laſt drop, which remains upon the edge of the phial, may be eaſily wiped off in the former conſtruction, viz. by gently rubbing the beak upon the edge of the other phial, into which the liquor is poured; whereas in the laſt-mentioned conſtruction it can hardly at all be avoided to let that drop run down the outſide of the phial; which is not only diſpleaſing, but alſo dangerous, when thoſe liquors are ſtrong acids, or alkalies.

The inſtruments of the third claſs are thoſe neceſſary to ſhew the various properties of different ſorts of elaſtic fluids. The reader may eaſily imagine, that a very great variety of inſtruments is neceſſary for this purpoſe, becauſe almoſt every particular property requires a different apparatus; however ſeveral of the inſtruments deſcribed above may, with a little variation, be applied to many of thoſe purpoſes; as for inſtance, the common receivers ſerve to ſhew whether or no any particular ſort of elaſtic fluid is capable of aſſiſting combuſtion; how far it may be abſorbed by water, &c.: but yet ſome properties cannot be examined or uſed without particular inſtruments, the principal of which we ſhall deſcribe in this chapter, reſerving to ſpeak occaſionally of thoſe that are of leſs conſequence in other places of this work.

Thoſe inſtruments are the following, viz. The apparatus for impregnating water or other fluids with fixed air; the receiver neceſſary to tranſmit electric ſparks through any particular ſort of elaſtic fluid; the receiver to fire inflammable air by means of an electric ſpark, and to retain it after the exploſion; the piſtols which ſhew the force of inflammable air exploding together with common or dephlogiſticated air; the eudiometer, or inſtrument neceſſary to obſerve the degree of purity of reſpirable air by the diminution ariſing from its combination with nitrous air; and the inſtrument neceſſary to examine the ſpecific gravities of the various elaſtic fluids.

Fig. the 13th, repreſents a ſection of the apparatus neceſſary to impregnate water with fixed air. This elegant inſtrument was firſt invented by Dr. North, and a deſcription of it was publiſhed in the Philoſ. Tranſactions, vol. LXV. for the year 1775, and afterwards received ſome improvements; in which ſtate it is here repreſented. It conſiſts of three glaſs veſſels S, T, V, fitted into one another by grinding. The lower veſſel V, beſides the large neck into which the bottom of the ſecond veſſel is ground, has another ſmall aperture *a*, to which a glaſs ſtopple is fitted. The ſecond veſſel T has three apertures, viz. the upper and larger one, which receives the under part of the veſſel S; the lateral aperture *b*, to which a glaſs ſtopple is fitted; and the under aperture, by which this veſſel communicates with the veſſel V; but this aperture is furniſhed with a valve, whoſe parts are diſtinctly ſhewn by c, d, e, upon a larger ſcale. The piece *c* is a perforated cylinder ground into the extremity of the veſſel T. The piece *e* is a like cylinder, perforated with many capillary holes, which is fitted by grinding into the ſame extremity, but above the piece *c*; a ſmall ſpace remaining between thoſe two cylinders, in which a plano-convex lens *d* can freely move. The plane ſurface of this lens is downwards, ſo as to cover the hole of the piece *c*. In this manner it may be eaſily conceived, that a fluid can paſs from the veſſel V into T, but cannot go backwards from T into V. The third veſſel S terminates in a long bent tube, which goes into the veſſel T. Its other aperture *f* has a glaſs ſtopple, which is very acutely conical, ſo that a very ſmall force from within the veſſel can riſe it up. In the lowermoſt veſſel of this apparatus the chalk and diluted oil of vitriol is put; the ſecond veſſel is filled with water, and the whole apparatus is put together to work in the manner exhibited by fig. 15. Now, as the fixed air is produced from the materials in V, it paſſes through the valve into the veſſel T, and neceſſarily goes to the upper part of it; and becauſe this veſſel is filled with water, the fixed air preſſing upon the water will force it into the empty veſſel S. In this manner the water that remains in the veſſel T, being in contact with the fixed air, which paſſes continually through it, becomes gradually impregnated with that elaſtic fluid, and it may be drawn out through the aperture *b*, in which caſe the water forced into the veſſel S returns backwards into the veſſel T. This impregnation may be much accelerated by ſhaking the apparatus; for then the fixed air is made to touch a greater ſurface of water. The impregnation of water with fixed air in this apparatus is facilitated alſo by the preſſure of the column of water (for preſſure facilitates it conſiderably) raiſed in the veſſel S; which preſſure might be ſtill more increaſed by adapting a ſafety-valve (like thoſe uſed for fire-engines) to the neck *f* of the veſſel S, inſtead of the glaſs ſtopple *. To the aperture *b* of the middle veſſel, ſometimes a glaſs ſtop-cock is fitted inſtead of the ſtopple. The aperture *a* of the loweſt veſſel is uſeful to introduce any materials into the veſſel, or to ſtir its contents whilſt the proceſs is going on. Before the invention of this apparatus, the fixed air was made to paſs through a bladder into a phial partly filled with water; but repeated experiments have ſhewn, that the bladder always imparts a diſagreeable taſte to the water, which is not at all the caſe with the above-deſcribed glaſs apparatus.

The glaſs-receiver A B, repreſented in fig. 16, is uſeful

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* In order to increaſe this preſſure gradually, and to any required degree, Mr. Warltire propoſed to adapt a mercurial gage upon the veſſel S, viz. a tube filled with quickſilver; but this gage is not eaſily manageable.

when

when electric ſparks muſt be tranſmitted through any ſort of elaſtic fluid. The diameter of this receiver is about three inches, and its height is a little more than one foot. At about three inches from the top of it two oppoſite holes C C are drilled, into which two knobbed wires are fitted by grinding, ſo that their extremities within the receiver may come within two inches of each other. Theſe wires ſhould be made ſo as to be eaſily taken off and replaced; and ſeveral ſets of them ſhould be had, viz. two of iron, two of braſs, two of pure ſilver, &c. in order to try the difference ariſing from tranſmitting the electric ſparks through wires of different metals. That the holes C C might be ſufficiently long to hold the wires ſteady, the ſubſtance of this receiver ſhould be very thick, for inſtance, of a quarter of an inch. Some perſons have uſed to cement the wires into the holes; but the cement, in ſome nice experiments, may render ambiguous their reſult. When this veſſel is wholly or partly filled with any elaſtic fluid *, and is put into a baſin containing water or quickſilver, the prime conductor of an electrical machine muſt be brought within two or three inches of one of the knobs E or D, and by means of a wire, a chain, or by putting the hand on it, the other knob muſt be connected with the floor of the room, viz. by means of good

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* The quantity of elaſtic fluid ſhould at leaſt fill as much of the receiver as that the wires may be about the middle of it, viz. equally as far from the top of the receiver as from the ſurface of the water or mercury in it.

conductors of electricity. In this ſituation, if the electrical machine is put in action, the ſparks will leap from the prime conductor to one of the knobs of the inſtrument A B, and at the ſame time will paſs through the elaſtic fluid contained in the receiver. Although the inſide ſurface of this receiver is conſiderably damp, yet the electric ſparks, when the machine is powerful, will paſs from wire to wire through the elaſtic fluid, rather than through the moiſture adhering to the inſide ſurface of the glaſs. As the quantity of elaſtic fluid to be examined with this inſtrument is ſometimes very ſmall, it would be not amiſs to have two of thoſe receivers, viz. one like the above-deſcribed, and another of half its dimenſions.

Fig. 17th, repreſents the inſtrument neceſſary for the combuſtion of inflammable air, when the elaſtic fluid is required to be retained after the exploſion. It conſiſts of a glaſs veſſel ABC, nearly in the ſhape of a bell. Its cavity near the top being not above one inch in diameter; a little above the middle, as at GG, being about two inches in diameter; and laſtly, the aperture BC, being about ſix inches. The ſubſtance of the glaſs in this receiver muſt be very thick, eſpecially towards the top, where two oppoſite holes D D muſt be drilled, and two knobbed wires ED, FD, muſt be nicely fitted into them by grinding. The extremities of theſe wires within the receiver ſhould come within a quarter of an inch of each other. When this inſtrument is to be uſed, it is firſt filled with water, and inverted into the tub, then a ſmall quantity of inflammable air, mixed with common or dephlogiſticated air, is thrown in it, which will go to the top A of the inſtrument; ſo that the extremities of the wires will be in this mixture of elaſtic fluids. Now if by means of a wire the outſide of a charged electric jar be connected with one of the knobbed wires, viz. E or F, and the knob or inſide of the jar be brought nearly into contact with the other knob F or E, the diſcharge of the jar will happen, and the ſpark, which paſſes between the extremities of the two wires within the receiver, will ſet fire to the inflammable air, which will conſequently explode, giving a great concuſſion to the water in the tub; and if its quantity is too great, or the glaſs receiver is not ſufficiently ſtrong, it will break the inſtrument with great violence. When the inflammable air is fired, the inſtrument muſt be held with the hand applied about GG, and muſt be removed from the ſhelf of the tub; otherwiſe it will be broke very eaſily.

Fig. 18th, repreſents a ſmall piſtol, neceſſary to ſhew the force of exploding inflammable air. Since theſe inſtruments were introduced, their form has been very much diverſified; ſome having been made of braſs, and ſo large as to drive a leaden bullet; others have been made of tin, &c.; but that ſhewn by this figure is of glaſs, and ſo ſimple, that it may be eaſily conſtructed, even by perſons of no great genius; and gives a ſufficient idea of the power of exploding inflammable air, by driving a cork to a conſiderable diſtance.

ABD is a ſtrong glaſs tube five inches long, and about half an inch in diameter. Into the inſide of this tube, and towards one extremity of it, a ſmall ſlip of tinfoil CB is paſted, ſo as to be about two inches within the tube, and be turned on the outſide of it at B. Into this ſame extremity BD the ſmall wire GH, knobbed at its extremity H, muſt be cemented very faſt. The beſt method is to cement the wire into a ſmall glaſs tube F, and then to wrap ſome cotton or thread round this ſmall tube, and to cement it into the extremity BD of the piſtol *. The end G of the wire ſhould be bent towards the ſlip of tinfoil C, ſo as to come within about one tenth of an inch of it. Now when this piſtol is required to be charged, the inflammable air ſhould be kept in a corked bottle, to the mouth of which the aperture A of the piſtol muſt be applied very cloſely, in the ſame moment that the cork is removed, keeping the piſtol inverted over it. In this caſe it is plain, that the common air, which is in the piſtol, will mix with the inflammable air, becauſe the former being ſpecifically heavier than the latter, will deſcend into the

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* The cement to be uſed for this purpoſe ſhould be made by mixing in an earthen pan, over a gentle fire, equal parts of bees-wax and roſin, to which may be added a ſmall quantity of vermilion, merely to give it an agreeable red colour. Sealing-wax may be alſo uſed for this purpoſe, but it ſhould be of the ſofteſt kind, otherwiſe it will eaſily crack the tube.

the bottle, &c. When the piſtol has been thus kept over the bottle for about ten or fifteen ſeconds, it muſt be removed, and both the piſtol and the bottle muſt be inſtantly corked *. If now this charged piſtol be held by applying the thumb and fingers to the lower part of it, ſo as to touch the tinfoil B, and an electric ſpark be given to the knob H, by approaching it to the prime conductor of an electrical machine, or to the knob of a ſmall charged electric phial; the inflammable air in the piſtol will be fired by the ſpark, which will neceſſarily paſs between G and the tinfoil C, and will drive the cork I to a conſiderable diſtance. The above-mentioned bottle filled with inflammable air is ſufficient to charge the piſtol ſeveral times ſucceſſively, without being again filled with inflammable air, eſpecially if it is pretty large; only it ſhould be minded, that when the piſtol has been filled out of the ſame bottle ſeveral times, the inflammable air in that bottle becomes mixed with a good deal of common air, for which reaſon the piſtol ſhould then be kept ſome time longer upon the bottle, in order to charge it. Sometimes the piſtol will not explode, which is owing to its having been kept too long a time over the bottle, ſo as to become

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* One perſon alone, after ſome experience, may eaſily perform this operation by himſelf; but in general it is much more convenient to have an aſſiſtant, who may cork the bottle at the ſame time that the operator corks the piſtol.

filled entirely with inflammable air †; the common air contained in it being deſcended into the bottle in conſequence of its greater ſpecific gravity.

Fig. 19th, repreſents a braſs piſtol for inflammable air, which is more commonly ſold at the philoſophical inſtrument ſhops. It is here repreſented as tranſparent, in order to ſhew its internal conſtruction. It conſiſts of a braſs chamber ABC, to the mouth of which A a cork is fitted. To the bottom of it a perforated braſs piece is ſcrewed, into which a glaſs tube DE is cemented, and into this tube is cemented a wire GF, furniſhed with a knob F at one end, and bent at the other extremity, ſo as to come within about one or two tenths of an inch of the braſs piece. Fig. the 20th, ſhews this braſs piece ſeparate, and alſo the braſs cap I, which, when the piſtol is not uſed, is ſcrewed at H, in the manner ſhewn by the dotted line, and ſerves to defend the tube E. This piſtol is charged and diſcharged in the ſame manner as the glaſs one deſcribed above, but, being much larger, it requires a greater quantity of inflammable air, and conſequently makes a greater exploſion.

It is eaſily comprehended, that in the piſtols deſcribed above, there cannot be introduced a mixture of inflammable and common air in any required proportion, much leſs can there be introduced a mixture of inflammable and dephlogiſticated air. In order to avoid this great inconvenience, Dr. INGENHOUSZ contrived a piſtol, into which any required mixture of elaſtic fluids may be introduced*. This piſtol, and its ſeparate parts, are exhibited in fig. the 21ſt, plate II. A *a* is the barrel of the piſtol. B is the box or chamber for the elaſtic fluids. *b* the place where the barrel is ſcrewed to the box. C the handle of the piſtol. D is the wire or handle of the piſton LK, the lower part of which, *h h*, is made ſquare, in order to prevent its turning round. E is a hole on the ſide of the box, which is occaſionally ſhut, by ſcrewing the ſmall nut *e* in it. F is a piece of braſs with a female ſcrew, which is fixed to the wooden handle by means of three ſtrong ſcrews, and to which the lower part *f* of the box is ſcrewed. G is a piece of ivory fixed to the piſton. K is the piſton with a conical ivory termination L, which fits the conical end of the box. M is the perforation in the wooden handle, through which the braſs wire D paſſes. N is a ſmall braſs ball at the extremity of a wire, which paſſes through the canal R in the ivory cone. O is another piece of wire which paſſes through another hole, and touches the braſs under the ivory piece. The wires are both fixed into the holes by means of the cement mentioned above. P is the ſmall interval between the extremities of the two wires, through which the electric ſpark paſſes, when given by means of a charged electrical bottle to the ball N.

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† The reader may remember our having remarked above, that when inflammable air is not mixed with reſpirable air, it will not explode.

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* Philoſ. Tranſ. vol. LXIX. page 410.

When the parts of this piſtol are put together, as ſhewn by ABCD, the piſton is pulled back, ſo as its part K may be at F, and the box is filled with inflammable and reſpirable air; the electric ſpark given to the ſmall braſs ball, as mentioned above, will inflame the gas, and its force will puſh a bullet, which is previouſly fixed into the barrel juſt where this is ſcrewed to the box. But in order to charge the piſtol with a mixture of inflammable and common air, or inflammable and dephlogiſticated air, in any required proportion, the piſton muſt be puſhed towards the conical part of the piſtol, then unſcrewing the barrel, the aperture of the piſtol is applied to the neck of the bladder containing the mixture of inflammable and common or dephlogiſticated air, and drawing back the piſton, that mixture of elaſtic fluids is introduced into the chamber or box of the piſtol.—This done, the bladder is detached from the extremity of the piſtol, and at the ſame time a ſmall leaden bullet, wrapped up in ſoft leather, is applied to the ſaid aperture, and the barrel is ſcrewed over it *; thus the piſtol is charged, and is now ready to be

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* This operation of detaching the bladder, applying the bullet, and ſcrewing the barrel, muſt be done with quickneſs and dexterity, in order that ſome of the introduced elaſtic fluid may not eſcape out of the piſtol, and ſome common air enter in its ſtead.

be fired.—The real ſize of the piſtol is about three times larger than the figure.

One of the moſt uſeful diſcoveries made in this branch of natural philoſophy is the method of aſcertaining the purity of reſpirable air by the taſte of nitrous air, which was made by Dr. PRIESTLEY. By this diſcovery not only the purity of the elaſtic fluid produced in various experiments, but the ſalubrity of the air in various parts of the earth, is aſcertained, which is of great conſequence for the welfare of mankind; hence philoſophers have ſpared no pains in endeavouring to contrive accurate and expeditious inſtruments for this purpoſe, and indeed ſeveral of them have been produced, which plainly ſhew the ingenuity and knowledge of the reſpective inventors; but at laſt thoſe inſtruments ſeem to have undergone the ſame fate as *barometers*, viz. after various complicated conſtructions, the ſimpleſt of them has been found to anſwer the beſt. However I ſhall here give the deſcription of the principal of them, becauſe ſome have peculiar advantages, which may be uſeful for ſome particular purpoſes; and alſo becauſe I will not take upon me to determine which of them is more or leſs uſeful, without ſhewing at the ſame time to my reader, the reaſons for which ſome of them may be preferred to others. The eudiometer uſed by the original inventor, Dr. PRIESTLEY, is a divided glaſs tube, into which, after filling it with, and inverting it in water, one or more meaſures of common, and one or more meaſures

of

of nitrous air are introduced by means of a ſmall phial, which is called the *meaſure.* The ſpace, and parts of that ſpace, which one or more meaſures of air occupy in the tube being marked on the outſide of the ſaid tube, the diminution of the quantity of the two elaſtic fluids is ſeen at once. In ſhort, this eudiometer is the ſame as that which we deſcribed in the preceding chapter.

As ſoon as this diſcovery of Dr. PRIESTLEY was announced abroad, two Italian philoſophers, Mr. LANDRIANI and Mr. FONTANA, contrived particular eudiometers, deſcriptions of which they ſoon publiſhed to the literary world. Mr. LANDRIANI employed his eudiometer to obſerve the various degrees of the air's ſalubrity in different parts of Italy, and after his journey he ſent the inſtrument as a preſent to Dr. PRIESTLEY. Mr. LANDRIANI deſcribed one nearly of the ſame form in the ſixth volume of ROSIER's Journal for the year 1775. This inſtrument conſiſts of a glaſs tube fitted by grinding to a cylindrical veſſel, to which two glaſs cocks are adjoined, and a ſmall baſin; all which is adapted to a common wooden frame. In this inſtrument quickſilver is uſed inſtead of water. The principal inconveniences relating to the conſtruction and uſe of ſuch an eudiometer, are owing to its having glaſs cocks, which are difficult to be conſtructed, and are eaſily put out of order; and alſo to its being uſed with quickſilver, becauſe nitrous air acts upon quickſilver, and therefore may render the experiment ambiguous.

Mr.

Mr. Magellan, in the year 1777, publiſhed the deſcription of three eudiometers invented by himſelf, which are repreſented by the figures 22, 23, and 24, plate II. The firſt of thoſe, fig. the 22d, conſiſt of a glaſs tube, M D, about twelve or fifteen inches long, and of an equal diameter throughout, with a ground glaſs ſtopple M; to the lower extremity of which tube is fitted a veſſel C, by grinding; the form of which, as alſo the form of the lower extremity of the tube, are clearly ſhewn by the figure. The veſſel C, beſides the neck, which fits the lower extremity of the tube, has two other necks, into which two equal phials, A and B, are adapted alſo by grinding. The capacity of both thoſe phials is nearly equal to that of the tube M D. Z repreſents a braſs ring, which ſlides up and down the tube M D, and by a finger-ſcrew may be made tight at any place upon it. G repreſents a braſs or wooden ruler, which is divided into equal parts, and has two ſemicircular braſs pieces, by which it may be eaſily applied and kept near the glaſs tube M D, as it appears at F, where it muſt be kept cloſe to the neck or upper extremity of the tube by the notch I. The uſe of this inſtrument is the following: Firſt, the ſtopple M is removed, then the inſtrument being dipped into the water of the tub, is entirely filled with water, and the ſtopple is replaced, ſo that no bubble of air remains within the tube or the veſſel C, and the two phials A, B.—This done, the lower part of the inſtrument, viz. about as far as the middle of the tube,

muſt be kept under water, and one of the phials, A or B, which now is filled with water, is removed from the neck of the veſſel C, and is filled with that air, whoſe purity muſt be tried, after the manner ſhewn in the preceding pages; then is replaced into the neck of the veſſel C. In the ſame manner the other phial, A or B, is filled with nitrous air, and is replaced into the other neck of the veſſel C. Now the inſtrument being out of the water, and keeping it in the ſame ſituation as it was in the water, viz. with the tube erect, the veſſel C muſt be turned with the bottom *b* upwards, as it is repreſented at F; in which caſe the two elaſtic fluids contained in the phials A and B, will aſcend into the veſſel C, where mixing together, the diminution will be effected. But as ſoon as the veſſel C is turned round, the inſtrument muſt be plunged in water as far as about the middle of the tube, and the ſtopple M muſt be removed. According as the bulk of the two elaſtic fluids diminiſhes, the water in the tube M D deſcends. "I then," ſays the author, "obſerve with at-
"tention the moment when the mixture of the two kinds
"of air comes to its greateſt diminution, after which its
"bulk will begin to increaſe again. In order to catch
"this moment with certainty, I ſlide down the braſs ring
"Z of the inſtrument, as the ſurface of the water in the
"tube falls. This point of the greateſt diminution will
"be eaſily perceived, by obſerving when that inſide ſur-

" face is ſtationary; which will happen in a few minutes, " if the nitrous air has a proper ſtrength *.

" As ſoon as the diminution of the two kinds of air " appears to be ſtationary, I fill up the whole tube of the " eudiometer with water: I ſhut it up with the ſtopple M, " and incline the top of the inſtrument forwards, till the " air comes from the veſſel C up to the top N of the tube. " I then keep the lower part of the inſtrument dipped in " water; take off the glaſs veſſel C, with the two phials " A, B, and raiſe or lower the tube of the eudiometer, ſo as " to ſee the ſurface of the water in the inſide even with " that on the outſide, which I mark, by ſliding to it the " braſs ring Z. Otherwiſe I apply the ruler G (without " making any uſe now of the braſs ring) to the ſide of " the eudiometer, whilſt it is immerſed in the water of " the trough; and there I ſee the true dimenſion of the " remaining bulk of the two kinds of air already dimi- " niſhed. Perhaps the beſt method for this obſervation " would be, to allow time enough, that the mixed air " may take its ſettled bulk; but this requires ſometimes " twenty-four hours time.

" The number marked about the middle of this ruler G,

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* Here Mr. MAGELLAN adds a note, in which he ſays, that the increaſe of the mixture of the two elaſtic fluids, after its being decreaſed to a certain degree, is a phenomenon which he thinks he has obſerved the firſt in thoſe experiments. This phenomenon will appear in the following pages to have been a miſtake.

“ as for inſtance, * * = 96, means that the contents of
“ both phials, A and B, are equal to ninety-ſix diviſions
“ of the ruler, when put into the tube of that eudiometer;
“ that is to ſay, they are equal to a ſolid cylinder, as
“ thick as the inſide of the glaſs tube, and whoſe length
“ is ninety-ſix diviſions of the ruler, which has been di-
“ vided into tenths of an Engliſh inch. Now if, for in-
“ ſtance, this remaining bulk of mixed air correſponds to
“ the 56th diviſion of the ruler, it ſhews that, out of
“ 96 parts, only 40 (=96—56) have been loſt or con-
“ tracted; and, in this caſe, the wholeſomeneſs of that air,
“ which I call A, will be $\frac{40}{96}$. If another equal quantity
“ of different air, which I ſhall call B, had alſo been tried
“ by the ſame eudiometer, and its reſiduum was equal to
“ 60 parts of the ſame ruler, the reſpective ſalubrity of
“ the air B will then be to that of the air A, as 36
“ (= 96—60) to 40[*].

To perſons who have a knowledge of the principles of hydroſtatics, it will appear, that the above-deſcribed inſtrument is ſubject to ſome errors, which may ariſe from a greater or leſs preſſure of the column of water upon the elaſtic fluid in the veſſel C, which may eaſily vary, according as the inſtrument is kept more or leſs perpendicular: it may vary alſo by the very act of putting the ſtopple M; but the greateſt fault attending the uſe of this eudiometer is, its not admitting more than one meaſure of nitrous air to be mixed with common air; which, as it will appear in the ſequel, is a very uncertain method of eſtimating the degree of purity of a given ſort of reſpirable air. The diviſions alſo upon the ſcale of this eudiometer are not ſmall enough to ſhew very ſmall differences, nor does the whole conſtruction of the inſtrument ſeem capable of accuracy.

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[*] Mr. Magellan's deſcription of a glaſs apparatus, &c. together with the deſcription of ſome new eudiometers.

The ſecond eudiometer of Mr. MAGELLAN I ſhall deſcribe exactly in the author's own words. See fig. 23, plate II. " It conſiſts of a glaſs tube T C, two or three feet " long, and of a uniform diameter: the end C is bent " forwards, and the other end T is wide open, as a funnel, " unleſs a ſeparate one is made uſe of: this tube is " faſtened by two loops, to the braſs ſcale C W T V. " There is a glaſs phial N, the neck V of which is ground " air-tight to the end T of the tube, and contains only " half of the whole inſide capacity of the divided tube " C T. It has, at the other end C, a large round phial " A B C, containing three or four times the bulk of the " phial N: its neck is alſo ground air-tight to the mouth " C of the tube." The braſs ſcale C W T V, is divided into 128 parts; which diviſions are ſet from T towards C. The cavity of the tube, between the firſt and laſt of thoſe 128 diviſions, is equal to twice the capacity of the phial N. " Beſides this, there is a tin veſſel X R, which " may ſerve as a packing-caſe for the whole inſtrument,

" and its neceſſary appendages; and alſo as a trough, when " experiments are made; it being then filled with water. " Both the glaſs tube *g h*, and the glaſs ſtopple M, belong " to this eudiometer; and both are fitted in, air-tight, to " its mouth V."

In order to uſe this eudiometer, " Let the inſtrument," ſays the author, " be immerſed under the water of the " tin veſſel, and let the phial N, filled with water, be " put in the inſide ſocket C E D, of the tin veſſel. Let " it be filled with nitrous air, and let this quantity of " air be thrown into the phial A B C, which I fix a little " tight to the mouth C of the eudiometer. I afterwards " fill the ſame phial N with the air I want to try; and " raiſing the end C of the inſtrument, I put it into its " mouth V: when this is done, I ſet the inſtrument up- " right, as repreſented in the figure, hanging it on the " hook W; and as ſoon as this laſt air goes up to the phial " A B C, I take off the phial N, that the diminution of " the two mixed airs may be ſupplied from the water in the " tin veſſel; which muſt be the caſe, as the mouth V of " the eudiometer is then under the ſurface of the water.

" I then put to the lower end V of the eudiometer, the " bent tube *g h*, to which is fitted the braſs ring K, and " is filled with water. It is by obſerving the ſurface of " the water in this ſmall tube (which then forms a true " ſyphon with the tube of the inſtrument) and by means " of the braſs ring K, that I can diſtinguiſh the ſtationary

" ſtate of the diminiſhing bulk of the two mixed airs, " above-mentioned; which being perceived, I take off " the ſmall tube *g h* from the eudiometer, and lay down, " for ſome minutes, the whole inſtrument, in an horizontal " tal poſition, under the water of the tin veſſel: I ſhut " up the mouth V with the glaſs ſtopple M, and reverſing " ing the inſtrument, I hang it up by the end V, on the " hook W. By this poſition the whole diminiſhed air of " the veſſel A B C goes up to the top, where its real bulk " is ſhewn by the number of the ſcale, facing the inſide " ſurface of water. This number being deducted from " 128, gives the comparative wholeſomeneſs of the air " already tried, without any farther calculation.

" But this proceſs will be ſtill eaſier, when the laſt diminution " nution of the two mixed kinds of air is only required " in the obſervation; becauſe no uſe will be then made of " the ſyphon. In ſuch a caſe, the inſtrument is left hanging " ing on the hook W, for 48 hours; after which it is laid " down under the water of the trough, in an horizontal " poſition, for 8 or 12 minutes, in order to acquire the " ſame temperature of the water: the mouth V is then " ſhut up with the ſtopple M; the inſtrument is hung by " the end V in a contrary poſition; and the laſt real bulk " of the good mixed air will be then ſhewn by the number " ber of the braſs ſcale, anſwering to the inſide ſurface of " the water."

In this inſtrument the intelligent reader may eaſily perceive a needleſs complication of parts, and a troubleſome proceſs. The cauſes of errors are many, but the principal will be taken notice of after we have deſcribed the third eudiometer of the ſame author, which is ſubject to many ſimilar defects.

" This third eudiometer conſiſts of a ſtraight glaſs tube " EN, fig. 24, plate II. of a uniform diameter, about " two or three feet long, with a large ball S, and a glaſs " ſtopple M, fitted air-tight to the mouth N, which ought " to be wide open, as a funnel, unleſs a ſeparate one is " made uſe of. There is alſo a ſmall ſyphon K L, with a " braſs ring X: a ſmall phial Z, the contents of which " may be received in the third part of the ball S; and " when put into the glaſs tube, muſt take there no more " than the half of its length. Laſtly, this inſtrument has " a ruler I, which is divided and ſtamped like that other " already deſcribed; and a glaſs funnel, which is ground " to the mouth N of the inſtrument, when this is not " wide open, as already ſaid."

The uſe of this inſtrument is as follows:

" Firſt, it is filled with water, and ſet in a vertical poſition, with the mouth N under the ſurface of the water, in a tub, or in a trough. Secondly, the phial Z is " filled as above with *nitrous air*; and thrown into the " tube by means of the glaſs funnel, which is ground to " the mouth N of the eudiometer, unleſs it be wide " enough not to be in need of any funnel. Thirdly, the

" ſame phial Z is again filled with the air to be tried; and " thrown into the ſame. Fourthly, the ſyphon K L is " added immediately to the mouth N of the eudiometer, " under the ſurface of the water; ſome of which is to be " poured into it.

" Fifthly, the ſtationary moment of the greateſt dimi- " nution of the mixed air at S, is watched by means of the " ring X, as mentioned above. Sixthly, when that mo- " ment arrives, the ſyphon K L is taken off; the eudi- " ometer is laid for ſome minutes under the water, in an " horizontal poſition, or nearly ſo, but in ſuch a manner " that no part of the incloſed air may get out; the mouth " N is ſhut up with the glaſs ſtopple M, and the inſtrument " is inverted with the mouth N upwards. Laſtly, the " ſpace occupied by the reſiduum of the diminiſhed air, " is meaſured by applying to its ſide the divided ruler, or " ſcale, and the reſult is eſtimated after the manner al- " ready explained."

The Author, in his deſcription of the above-mentioned eudiometers, adds various other cautions to be uſed in conducting the experiments, &c.; and he remarks ſeveral neceſſary particulars relating to the uſe of thoſe inſtruments, but I think it unneceſſary to take any notice of them here, ſince the reader may be aſſured that thoſe inſtruments are quite uſeleſs for the purpoſe, for which they are intended. Some reaſons to ſupport this aſſertion have already been mentioned in the preceding pages, but the principal will appear in the following. The reader muſt have remarked, that the conſtruction of the above-mentioned three eudiometers is principally founded upon the remarkable phenomenon which Mr. MAGELLAN ſaid to have diſcovered; namely, that the bulk of nitrous and common air, after a certain degree of diminution, increaſes for a ſhort time. Now this phenomenon was nothing more than a miſtake of the author, owing I cannot imagine to what cauſe; for when I acquainted him, that after repeated trials I could not obſerve it, he frankly acknowledged, that it muſt have been occaſioned by ſome miſtake in his former experiments; for he could not now obſerve it himſelf.

From this it appears, that great part of the appendage belonging to the above-deſcribed three eudiometers, is uſeleſs; but the moſt direct proof of the little uſefulneſs of thoſe inſtruments, will appear from the reſult of ſome experiments actually tried with them. As I was by my own experience convinced of the inconſtancy of the experiments tried with thoſe inſtruments, I requeſted of Mr. MAGELLAN to ſhew me the experiments himſelf, to which he obligingly conſented. The inſtrument he uſed was his firſt-deſcribed eudiometer, with which he tried the air taken out of the window of that room in which the experiments were performed. By the firſt trial, the diminution of the joint bulk of both elaſtic fluids, viz. the nitrous and the common air, was 48 parts out of 132 (which is equal to the capacity of both the phials, A B fig. 22. plate II.) By a ſecond trial, the ſame elaſtic fluids being always uſed, the diminution was 58 parts out of 132; viz. 10 parts more than before. By a third trial, the diminution was again 48 parts; and by a fourth trial, it was 51 parts out of 132. From this it plainly appears, that with ſuch an inſtrument one cannot depend upon a greater degree of accuracy than within, at leaſt, 10 parts out of 132, or upon about one 13th part of the quantity of both elaſtic fluids. Now, by very accurate experiments, to be mentioned in the courſe of this work, it will appear that if a mixture of equal quantities of common and nitrous air be diminiſhed with proper method, and then equal quantities of atmoſpheric air, contaminated ſo that a candle will not burn in it, together with nitrous air, be alſo diminiſhed by the ſame method; the difference of thoſe two diminutions will be about one 13th of the whole quantity of elaſtic fluids employed in each experiment; therefore it follows, that by the above-mentioned eudiometer of Mr. MAGELLAN, one cannot find any certain difference between common reſpirable air, and ſuch air wherein a candle will not burn*. The reader may hence judge how little we can depend upon the experiments made with thoſe inſtruments, in order to aſcertain the degree of purity of the atmoſpherical air in various parts of the world, and even at various trifling heights above the ground in the ſame town, or near the ſame building; where the difference, if any difference at all exiſts between the air of thoſe places, as ſome perſons have atteſted, is ſo ſmall as to be impoſſible to be aſcertained by means of thoſe inaccurate inſtruments.

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* Mr. MAGELLAN himſelf ingenuouſly acknowledged to me, that after many repeated experiments with his eudiometers, he deſpaired to obtain a conſtant reſult, even when the nitrous and common air that he uſed were preciſely of the ſame quality.

The beſt method hitherto known, by which the purity of the atmoſpheric or reſpirable air may be aſcertained, is that uſed by Mr. Fontana. The accuracy of this method is ſuch as can hardly be believed by perſons who have not obſerved it. We remarked above, that by Mr. Magellan's method, when the ſame kinds of elaſtic fluids were uſed, the difference between two experiments ſometimes amounted to one 13th of the whole quantity, or nearly one 7th of a meaſure; but the reader may be aſſured, that by Mr. Fontana's method, when properly performed, the error of ſimilar experiments very ſeldom amounts to one 50th of a meaſure. This method conſiſts rather in a nicety and uniformity of operation, than in the particular conſtruction of the inſtrument, which originally is nothing more than a divided glaſs tube, viz. the ſame in principle as that formerly uſed by Dr. Priestley. Indeed Mr. Fontana, towards the beginning of laſt ſummer, 1779, in order to avoid ſome ſmall errors, added a very complicated apparatus to his eudiometer, which rendered it rather inconvenient to manage, and ſeems altogether uſeleſs. I ſhall firſt deſcribe his ſimple eudiometer, and afterwards his laſt complicated apparatus; to which proper remarks will be added.

The glaſs tube was as nearly cylindrical, viz. of a diameter as uniform throughout, as can be diſtinguiſhed by meaſuring*. Its diameter was about three quarters of an inch; its length was about 18 inches, and was hermetically cloſed at one end. On the outſide of this tube marks were made, or circles were marked, with a diamond, at the diſtance of three inches from one another, beginning from the cloſed end of the tube; or at ſuch diſtances as are exactly filled by equal meaſures of elaſtic fluids. When the parts of theſe diviſions were required, the edge of a braſs ruler divided into inches and parts of an inch, was held againſt the tube, ſo that the firſt diviſion of the ruler might coincide with one of the marks on the tube, &c. Into this tube the nitrous and reſpirable air are introduced, diminiſhed, and meaſured; but in order to introduce a juſt quantity of elaſtic fluid in it, Mr. FONTANA contrived a meaſure, which is the only inſtrument hitherto known, that is capable of meaſuring always a conſtant quantity of elaſtic fluid. This meaſure is repreſented fig. 1, plate III: it conſiſts of a ſhort glaſs tube, A B, abut two inches long and one inch in diameter, cloſed at the end A, and to whoſe aperture B a braſs piece BCDE is cemented, which contains a ſliding door D, which, when puſhed into its proper cavity, ſhuts the mouth of the tube or meaſure AB, and when pulled out, as it is ſhewn in the figure, opens the ſaid aperture. In order to prevent the door D being pulled quite out, a ſpring E is ſcrewed upon the flat part of the braſs piece, the extremity of which bears upon the head of a braſs pin, which paſſing through a hole, rubs againſt the door D, and when this is pulled nearly out, the pin falling into a little cavity, prevents its being taken quite out. The opening or diameter of the braſs piece is nearly the ſame with that of the glaſs tube AB; and near its mouth C there are two notches *s s* made with the edge of a file, for a reaſon that will appear in the ſequel. In fig. 2, plate III. is exhibited a dotted repreſentation of the cavity of the braſs piece, and the ſeparate parts of the ſaid meaſure; viz. A the glaſs tube, B the braſs piece, C the ſliding braſs door, inverted ſo as to exhibit the cavity for the pin; D the pin, with the ſpring and ſmall ſcrew. It muſt be obſerved, that the inſide ſurface of the glaſs tube of this meaſure, and alſo the inſide ſurface of the eudiometer or long tube, ſhould be rubbed with fine emery, ſo as to take off the poliſh; in which caſe the water, when the experiments are tried, will not adhere to it in drops; conſequently the meaſuring by them will be more exact.

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* The way to obſerve whether a glaſs tube is perfectly cylindrical in its cavity, is to pour into it at different times equal weights of mercury or of water, one upon the other; obſerving each time, by means of a divided ruler, if thoſe equal quantities of liquor fill equal lengths of the tube.

This apparatus is uſed in the following manner:—The long tube is filled with water, and being turned with the mouth downwards, is left in the tub A B C D, fig. 1, plate II. (which is filled with water as far as one inch above the ſhelf) againſt the ſide B; then the meaſure, being alſo filled with water, is inverted over the hole *i* of the ſhelf of the tub, and, in order to fill it with the required ſort of elaſtic fluid, a phial containing that elaſtic fluid is brought with its mouth underneath the ſhelf, where being inclined a little, ſome of the elaſtic fluid is cauſed to eſcape from it, and to paſs into that excavated funnel under the ſhelf, which communicates with the hole *i*; from whence it will paſs through the hole *i* into the meaſure, which is inverted over it, and has its door open, that is, the ſliding-piece drawn out; at the ſame time the water, which before filled the cavity of the meaſure, eſcapes out through the notches *s s*, fig. 1, plate III *. This done, the door of the meaſure is ſhut, by puſhing it in as far as it will go, and the meaſure being drawn off from the ſhelf, but being ſtill kept under water, is turned with the mouth upwards, by which means the ſuperfluous quantity of elaſtic fluid, which being ſeparated by the ſliding-piece, remained in the cavity of the braſs piece, eſcapes out, and its place is occupied by water. Then the meaſure is again inverted with its mouth downwards, and is ſet any where upon the ſhelf of the tub, and there the door or ſliding-piece is opened. The reader may eaſily underſtand, that by this procedure a conſtant meaſure of elaſtic fluid may always be had. Now, after the meaſure is filled with that reſpirable fluid, which is required to be tried, the long tube is put with the aperture upon the hole *i* of the tub, where it is kept perpendicular, and the meaſure, being removed from the ſhelf, is brought under it, where it is turned with the mouth upwards, ſo that the elaſtic fluid may eſcape from it, and paſſing through the hole *i*, may enter the tube, where it will occupy the upper part of it as far as the firſt mark. Then the tube is again removed from the ſhelf, and is replaced againſt the ſide B of the tub, whilſt the meaſure is again filled with elaſtic fluid, after the manner mentioned above, &c.

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* Without thoſe notches the meaſure would ſtill be filled with the elaſtic fluid, but not ſo readily, becauſe the water could not get out of it with facility; hence the operation would be longer.

When Mr. FONTANA wanted to examine the degree of purity of common air, he uſed firſt to throw into the tube two meaſures of common air, one after the other, in the manner ſhewn above; then he added one meaſure of nitrous air, but as ſoon as this nitrous air was entered into the tube, he uſed to remove the tube from the ſhelf, and holding it by the top or cloſed end, agitated it in the water of the tub for about 20 ſeconds, after which he reſted it againſt the ſide B of the tub, whilſt he filled the meaſure again with nitrous air; then putting the tube upon the ſhelf, and holding it as nearly perpendicular as he could, applied the edge of the divided ruler to it, in order to obſerve the diminution of the two elaſtic fluids; for although three meaſures of elaſtic fluid had been thrown into it, which, if no diminution had taken place, ought to have reached as far as the third mark; their combined and diminiſhed bulk occupied about two meaſures, more or leſs a few parts of a meaſure, which were indicated by the divided ruler. After this Mr. FONTANA uſed to throw another meaſure of nitrous air into the tube, and after ſhaking and letting it reſt awhile, obſerved again the diminution of theſe four meaſures of elaſtic fluid, viz. two of common, and two of nitrous air.—The reaſon of obſerving theſe two diminutions rather than one, and eſtimating the purity, &c. from them, will appear in the ſequel. That this method of Mr. FONTANA ſhould be very accurate, may perhaps appear ſomewhat myſterious; but the myſtery will ſoon vaniſh, if it be conſidered, that the accurate reſult depended not ſo much upon the particular conſtruction of the inſtrument, as upon the regular management of it, and uniformity of operation. Indeed the exactneſs of the meaſure contributed a great deal; but Mr. FONTANA having obſerved, that with exactly the ſame quantities of nitrous and common air, very different reſults could be occaſioned by their being left a longer or ſhorter time before the inſtrument was agitated, by being agitated a great deal or a little, and by other circumſtances, which would ſeem trifling to a ſuperficial obſerver; took care to perform the operation always in a ſimilar manner, viz. to agitate the tube for the ſame length of time, to agitate it always with equal quickneſs, &c. by which means, when the ſame elaſtic fluids were uſed, the reſults of the experiments were ſo nearly the ſame, that the difference, if any could be obſerved, might have been neglected without impropriety.

Notwithſtanding the great accuracy of this method, Mr. Fontana endeavoured to render the reſult of ſuch experiment ſtill more preciſe, and, attentively examining the ſmall errors to which the above-mentioned method could be ſubject, contrived means to avoid them. Theſe errors were principally three, viz. firſt the elaſtic fluid within the tube, when the greateſt part of it is filled with water, and the tube is kept out of the water, excepting its mouth; is not of the ſame denſity with the outward or atmoſpheric air, on account of the pillar of water in the tube, which, according as it is longer or ſhorter, counterbalances, more or leſs, the preſſure of the atmoſphere upon the quantity of elaſtic fluid contained in the upper part of the tube; which quantity of elaſtic fluid conſequently occupies a greater or leſs ſpace, according as the pillar of water is higher or lower[*]: hence it appears very clearly, that if equal meaſures of elaſtic fluid are ſucceſſively thrown into the tube, the ſpaces occupied by the ſame are not equal; for inſtance, if the firſt meaſure occupies three inches length of the tube, the ſecond meaſure will occupy ſomething leſs than three inches length, becauſe, after introducing this ſecond meaſure, the pillar of water remaining in the tube (ſuppoſing that the tube is always ſet upon the ſhelf as mentioned above) is ſhorter than before; and ſo of the ſubſequent meaſures, &c.— This error, it is manifeſt, becomes inſenſible when the ſurface of the water within the tube comes nearly to coincide with the ſurface of the outſide water, viz. when the pillar of water within the tube is very ſhort.

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[*] In order to obſerve this truth very eaſily, take a glaſs tube about two or three feet long, and above a quarter of an inch in diameter, cloſed at one end, and after filling it with water, invert it in the water of the tub; then let a ſmall quantity of common air enter into it, ſo as to occupy about five or ſix inches of the tube, which may be done by lifting the mouth of the tube above the

The ſecond error was owing to the difficulty of keeping the inſtrument perpendicular in the act of meaſuring the diminution; and the third was the ſtill greater difficulty of obſerving with what diviſion of the ruler the ſurface of the water within the tube did coincide.

All theſe errors Mr. Fontana thought to avoid, beſides obtaining ſome other advantages, by the following contrivance;

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the ſurface of the water in the tub, and quickly immerging it again. This done, put a mark with a bit of ſoft wax upon the outſide of the tube, coinciding with the ſurface of the water in it; then let the tube be immerged more or leſs into the water of the tub, ſo as to render the pillar of water in it, longer or ſhorter, (meaſuring it from the ſurface of the water within the tube to the ſurface of the water in the tub) and it will be obſerved, that the ſurface of the water within the tube riſes accordingly above or falls below the mark; which ſhows that the air within the tube does not always occupy the ſame ſpace.

contrivance; but the complication of the mechaniſm, the difficulty of uſing and of properly conſtructing it, ſeem not to be ſufficiently compenſated by the real advantages gained.

A A A A, fig. 2, plate III. repreſents a ſtrong glaſs tube of about three inches in diameter, and eighteen inches long, with a foot or baſis of glaſs, all in one ſolid piece. Towards the upper end of this tube, viz. within about an inch of its mouth, is faſtened a braſs rim, which contains two braſs rings, which are moveable upon oppoſite centers, after the manner uſed for ſuſpending ſea-compaſſes;—they are commonly called *gingles*. C C C C is the meaſuring-tube or eudiometer, which is exactly as that deſcribed before, with lines marked upon its outſide ſurface, to ſhew the ſpaces occupied by equal meaſures of elaſtic fluid. Upon this tube is adapted the ſcale B B, which is repreſented ſeparately in figure the 3d; it conſiſts of two braſs ſlips A C, A C, connected by two braſs rings A A, C C, through which the eudiometer-tube paſſes. To the loweſt of thoſe rings is ſcrewed a perforated braſs piece B B, furniſhed with croſs pins or pivots; and by means of longitudinal cuts, its lower extremity is rendered ſpringy, ſo that when all the piece A B A B is put upon the eudiometer-tube, the latter cannot ſlip from within the former, unleſs the operator forces it. When the eudiometer-tube, with the ſcale, &c. is put together, as repreſented in fig. 2d, the croſs pins of the piece B B, fig. 3d, reſt upon the inner ring of the gingle at A A, fig. 2d, by which means the tube C C C C is kept perpendicular within the tube A A A A, provided this latter is ſituated ſo nearly perpendicular as the former may not touch the ſide of it, and be thus prevented to acquire a perpendicular direction. One of the braſs ſlips A C, fig. 3, plate III. is divided into equal parts, one hundred of which are equal to the ſpace between two of the marks on the eudiometer-tube C C C C, fig. 2, plate III; conſequently they ſhew the parts of a meaſure. The numeration of theſe diviſions, begins from the upper edge of the lower ring, which connects the two braſs ſlips A C A C.—The manner of uſing this inſtrument is the following:—One or more meaſures of reſpirable air are thrown into the eudiometer-tube C C C C with the meaſure, after the manner ſhewn above, to which is added one meaſure of nitrous air, and after ſhaking the ſaid tube for a ſhort time, it muſt be introduced into the large tube A A A A, which muſt neceſſarily for that purpoſe be intirely plunged into the water of the tub; for in this action the mouth of the eudiometer-tube C C C C muſt not be lifted out of the water. When the eudiometer-tube has been introduced into the large tube A A A A, the whole together is taken out of the water, and is ſet either upon a table or upon the ſhelf of the tub. Now the large tube A A A A is filled with water, and the eudiometer-tube is ſuſpended perpendicularly in it by means of the croſs pins or pivots of the braſs piece annexed to the ſcale, which reſt upon the inner ring of the gingle. The operator muſt then ſlide the tube C C C C up and down through the ſcale and braſs piece, &c. till the ſurface of the water within the tube coincides preciſely with the upper edge of the lower ring that connects the two braſs ſlips of the ſcale-piece, which may be done very accurately by means of a lens, which is ſometimes faſtened to the edge of the large tube as at D, but it is more convenient to hold it in the hand *. After fixing this point, it muſt be obſerved which diviſion of the ſcale coincides with one of the circular diviſion marked upon the glaſs tube C C C C, which will ſhew the parts of a meaſure. Thus, ſuppoſe that when the eudiometer-tube is fixed, ſo that the ſurface of the water in it coincides perfectly with the edge of the lower braſs ring, viz. with the beginning of the diviſions; that the ſeventieth diviſion of the ſcale falls upon the firſt circular mark of the ſaid tube, as it is ſhewn in the figure; then it is plain that the quantity of elaſtic fluid contained in the tube is equal to one meaſure, more ſeventy hundreds of a meaſure. When this quantity of diminiſhed elaſtic fluid has been thus obſerved, the large tube being immerged again into the water of the tub, the eudiometer-tube is removed from it, but always taking care that its mouth be

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* The ſurface of the water within the eudiometer is concave, and when viewed horizontally, it appears like a dark line or limit exceedingly well defined, ſo that the middle or loweſt point of it may be made to coincide with the edge of the braſs ring with great preciſion, except when ſome drops of water hang on the outſide of the tube, which ſhould therefore be wiped off.

not lifted above the ſurface of the water. Another meaſure of nitrous air muſt now be introduced into the eudiometer tube, after the manner mentioned above, then the tube is agitated as before—is introduced into the large tube A A A A—the whole is taken out of the water of the tub, and the quantity of elaſtic fluid contained in the tube C C C C, after this ſecond diminution, is obſerved after the manner directed above.

This apparatus keeps the eudiometer-tube perfectly perpendicular, and renders the pillar of water in it very ſhort; for, as the large tube A A A A is filled with water, which forms the office of a tub, when the ſurface of the water in the tube C C C C is made to coincide with the braſs ring, the pillar of water in the ſaid tube (meaſuring from the edge of the braſs ring to the ſurface of the water in the tube A A A A) is not above half an inch at moſt.

It is eaſy to obſerve, that if the operator, when furniſhed with the eudiometer-tube only, keeps it ſo far immerged into the water of the tub, when he obſerves the diviſions &c. that the water within the tube may be nearly equal with the edge of the tub; the large tube A A A A may be ſpared, and then the operation becomes much more eaſy and expeditious. The difficulty of keeping the tube in a perpendicular direction is a very trifling objection, ſince, when the limit of the ſurface of the water in the tube is determined by the braſs ring in the manner mentioned above, the difference ariſing from keeping the tube either perpendicular, or inclined a few degrees, is ſo very ſmall, that it may be ſafely neglected without fear of any ſenſible error.

In conſequence of theſe conſiderations, the method which I have uſed is founded upon the above-mentioned methods, partly uſed and partly rejected, ſo as to retain their uſeful properties and to avoid their inconveniences. This method will be deſcribed in the following chapter; whilſt I ſhall conclude the preſent with the recital of another method of determining the degree of purity of reſpirable air, by its diminution with nitrous air, uſed by Mr. De Saussure, Profeſſor of Philoſophy at the Academy of Geneva; who aſſerts that his method is more expeditious, more convenient, and more exact than the others.

His apparatus conſiſts of a cylindrical glaſs bottle, with a ground ſtopple, whoſe capacity may be about five ounces and an half; this bottle is the *recipient*, in which the two ſorts of elaſtic fluids are mixed—a ſmall glaſs phial, whoſe capacity is nearly equal to one third of the capacity of the recipient, which ſerves for a meaſure—a ſmall pair of ſcales, that may weigh very exactly—and ſeveral other glaſs bottles, like to the above-mentioned recipient, which ſerve to ſupply the place of the recipient, in caſe that is broken, and alſo to contain the nitrous or other ſorts of air. All this apparatus, together with that neceſſary to make the nitrous air, is packed into a box, which may be eaſily carried from place to place, and even to the ſummits of high mountains.

The operation is as follows.

Firſt, the recipient filled with water, cloſed with the glaſs ſtopple, and wiped on the outſide, is weighed very exactly; then it is immerged in a veſſel full of water, and being kept with the mouth downwards, the ſtopple is removed, and by means of a funnel two meaſures of common air, and one of nitrous air, are introduced in it one after another, which, as ſoon as they come into contact, are diminiſhed, and the water gradually enters into the recipient. In order to accelerate this diminution, the bottle or recipient is ſtopped and ſhook, then is opened under water, ſo as to let more water enter into it, inſtead of the diminiſhed quantity of elaſtic fluid; then it is ſtopped again, and ſo for three times ſucceſſively. At laſt the bottle is ſtopped under water, as before, but then it is taken out of it, and being wiped very clean and dry, is weighed very accurately. It is plain, that now this bottle, being filled partly with elaſtic fluid and partly with water, muſt be lighter than when it was quite full of water; the laſt weight, therefore, being ſubtracted from the former, the remainder ſhews the weight of that quantity of water, which would fill the ſpace occupied by the diminiſhed elaſtic fluid. Now in making ſimilar experiments with airs of different degrees of purity, the above-mentioned remainder will be greater when the diminution is leſs, or when the air is more impure, and contrarywiſe: hence the comparative purity between two or more ſorts of air may be determined *.

After the preceding obſervations upon the conſtruction and uſe of eudiometers, it ſeems almoſt uſeleſs to remark, that this method of determining the purity of reſpirable or atmoſpheric air is ſubject to many inconveniences, which are the inevitable ſources of error; the principal of which are, the inaccuracy

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* "Je pris un flacon de verre cylindrique, dont le diametre égaloit à-peu-près "la hauteur, qui pouvoit contenir environ 5 onces ½ d'eau, & qui ſe fermoit ex- "actement avec un bouchon de verre, uſé à l'Emeril.

"Ce flacon fut deſtiné à être le réceptacle, dans lequel je melerois les différens "airs avec l'air nitreux. Je le nommois le *récipient.*

"Pour meſurer les quantités d'air que je devois faire entrer dans ce récipient, "je cherchai une petite phiole, auſſi de verre, & dont la contenance fut à-peu- "près le tiers de celle du récipient: celle à la quelle je me fixai contenoit une "once, 6 gros, 12 grains d'eau; enſorte que le récipient contenoit trois de ces "*meſures*, & environ deux drachmes de plus.

"Je me pourvus outre cela d'une petite balance bien exacte, d'un petit en- "tonnoir, & de pluſieurs flacons de verre à-peu-près ſemblables au premier, & "qui ſe fermoient comme lui avec des bouchons de verre, uſés à l'Emeril. La "deſtination de ces flacons étoit de remplacer celui qui ſervoit de récipient, au "cas qu'il vint à ſe caſſer, & de ſervir à tranſporter d'un lieu à l'autre, les diffé- "rens airs que je voulois éprouver & comparer entr'eux.

"Ces bouteilles, ces balances, & ce qu'il faut pour préparer l'air nitreux, ſe "logent dans une boëte légere & peu volumineuſe, qui ſe tranſporte aiſément "& ſans danger au ſommet des montagnes les plus eſcarpées; on prend à "la derniere vacherie que l'on rencontre, un petit ſceau de bois, que l'on remplit "de la derniere eau qu'on trouve en montant. Avec cet appareil, on peut dans "l'eſpace d'une heure, faire ſept ou huit épreuves differentes, & obtenir une plus "grande exactitude qu'avec aucun des eudiometres fragiles & diſpendieux, qui "ſont compoſés de tubes & de robinets.

"Quand

inaccuracy of the meaſure, and the difficulty of ſtopping the bottle without occaſioning a preſſure upon the contained elaſtic fluid, which being variable, muſt occaſion ſome error or undeterminable difference in the weight of the bottle.

However, the method is very ingenious, and perhaps ſome practice, and even ſome ſmall variation in the apparatus, may render it ſufficiently uſeful and exact.

“ Quand je veux opérer, je commence par preparer, toujours ſuivant le meme procédé, la quantité d'air nitreux qui m' eſt néceſſaire. Des qu'il eſt pret, je remplis d'eau le récipient : puis le tenant renverſé dans l'eau dont le petit ſceau eſt rempli, j'y fais entrer à l'aide de l'entonnoir, d'abord deux meſures d'air commun, & puis une meſure d'air nitreux. Je vois ſur le champ les deux airs ſe meler avec efferveſcence, prendre une teinte orangée, & l'eau rentrer dans la bouteille à meſure qu'ils s'abſorbent réciproquement. Pour completer leur melange, je bouche la bouteille en la tenant toujours ſous l'eau, je la ſecoué dans l'eau meme ; après quoi je la debouche de nouveau, mais toujours en la tenant renverſée dans le ſceau plein d'eau, & il rentre ainſi une nouvelle quantité d'eau à la place de l'air qui s'eſt décompoſé ; je répéte trois fois cette opération, & toujours de la meme maniere dans chaque expérience. Lorſque le mélange des airs eſt ainſi parfaitement achevé, je bouche ſous l'eau la bouteille pour la derniere fois, je la retire, je l'eſſuye complettement, & je la peſe. On comprend que la bouteille ſe trouve d'autant plus peſante qu'il s'eſt abſorbé une plus grande quantité d'air, puiſque la preſſion de l'atmoſphere fait entrer de l'eau dans la bouteille, à meſure que l'air ſe détrait ou ſe décompoſe. Ainſi je trouve ordinairement après le melange, que la bouteille contient une once, 6 gros, 40 grains de plus qu'elle n'auroit fait, ſi au lieu d'y introduire un melange d'air commun & d'air nitreux, je n'y euſſe mis que d'une ſeule eſpece de ces airs, parce que par le melange il s'abſorbe une quantité d'air équivalente à un peu plus qu'une de mes meſures.”——*Voyages dans les Alpes* of Mr. De Saussure, 1779.

CHAP. VI.

The author's method of determining the degree of purity of air, and of meaſuring the quantity of permanently elaſtic fluid contained in an inverted glaſs veſſel, filled partly with it and partly with water, or other fluid.

IN the preceding chapter we took notice of the various methods of determining the degree of purity of reſpirable air, remarking thoſe particular defects, which rendered ſeveral inſtruments for that purpoſe, either uſeleſs or deſerving ſome alteration; but I have reſerved for this chapter the deſcription of a method, which being founded upon a due conſideration of all the others, and having been commonly uſed in the courſe of my experiments relative to this ſubject, ſeems to be the moſt expeditious, and, at the ſame time, accurate method hitherto known.

The apparatus, which, beſides the above-deſcribed tub and nitrous air, is requiſite for this purpoſe, is a glaſs tube or eudiometer, with its ſcale and a meaſure, ſuch as it was deſcribed above, and is repreſented in plate III, fig. the firſt. The tube is about 16 or 17 inches long, between $\frac{1}{2}$ and $\frac{2}{3}$ of an inch in diameter, and of an equal diameter throughout. One end of this tube muſt be ſealed hermetically, but the other muſt be ſhaped in the manner of a funnel, though not very wide.—

This may be eaſily done by means of a lamp and blowpipe. Fig. the 4th, plate III, repreſents ſuch an eudiometer, A B being the glaſs tube, to the upper or cloſed end of which a loop, A E C, ſhould be faſtened, which is made of waxed ſilk lace, and has ſeveral croſs threads C C, D D, E E, &c. The uſe of this loop is to ſuſpend the inſtrument to a hook A B, fig. 5, plate III, which ſhould be either faſtened continually to that ſide of the tub which is oppoſite to the ſhelf, or ſo conſtructed as to be eaſily removed and fixed again, as occaſion requires. Mine is formed of a thick braſs wire, the lower extremity of which fits a hole made in the ſide of the tub.

The braſs piece with the ſcale, which ſlides upon the eudiometer, is formed of two braſs ſlips, F G, H I, joined by two braſs rings F H, G I, to which they are ſoldered. Upon one of thoſe braſs ſlips are marked one hundred diviſions, beginning from the upper edge of the lower ring G I, and all together are equal to the ſpace contained between two of the marks or meaſures made upon the glaſs tube; ſo that they ſhew the parts of a meaſure. Upon the other braſs ſlip H I are likewiſe marked one hundred diviſions, but they begin from the lower edge of the upper ring F H.

N. B. Theſe diviſions muſt be made after the diviſions are marked upon the tube; which are to be made in the following manner:—

When the tube A B is filled with water, a meaſure of air

ſhould

ſhould be thrown into it, after the manner ſhewn in the preceding chapter; then the tube muſt be ſuſpended to the hook by the loop, as ſhewn in fig. 5, plate III; ſo high as that the ſurface of the water within the tube may be very near the ſurface of the water in the tub, as for inſtance, about two inches above it; then, looking horizontally through the tube, a mark ſhould be made, by ſticking a bit of ſoft wax upon the tube, juſt coinciding with the lower part of the ſurface of the water within it, in which place, afterwards, a circular mark ſhould be made with the edge of a flint, or with a piece of agate, or a diamond, but not ſo deep as to endanger the breaking of the tube. Thus the firſt meaſure is marked upon the tube, and in a ſimilar manner are the other meaſures alſo marked, viz. by throwing two meaſures of air into the tube, ſuſpending it, and marking it as before; then throwing in three meaſures, &c.

The attentive practitioner ſhould never venture to mark the tube with the indelible ſtroke of a flint, or diamond, after one trial, leſt he may make a miſtake; but he ſhould firſt put the ſeveral marks upon the tube with wax, then he ſhould repeat the operation once or twice more, in order to correct ſome errors, that perhaps might have been made the firſt time; after which he may proceed to mark his eudiometer with the edge of a hard ſtone, or even of a fine file.

The poliſh of the inſide ſurface of the tube A B, as well as of the meaſure fig. 1ſt, plate III, ſhould be taken off by rubbing it with fine emery. The operation, however, is very laborious.—At leaſt the meaſure ſhould be done ſo.

With this apparatus the degree of the air's purity muſt be tried, in the following manner:—

Firſt, fill the eudiometer-tube with water, taking care that no bubbles of air remain in it, and inverting it with the mouth downwards, leave it in the water, againſt the ſide of the tub. Secondly, fill the meaſure with that reſpirable elaſtic fluid that is required to be examined *. Thirdly, put the eudiometer-tube upon the ſhelf of the tub; keeping it perpendicular, and with the mouth exactly upon one of the holes of the ſaid ſhelf, and throw the meaſure of air into it. Fourthly, fill the meaſure again with the ſame air, and throw it likewiſe into the tube. Fifthly, fill the meaſure with nitrous air, and throw it alſo into the tube; but immediately

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* In order to perform this operation properly, the meaſure, filled with water, and having the braſs door open, is ſet upon one of the holes of the ſhelf of the tub; then a glaſs receiver, containing the required elaſtic fluid, is brought under that hole, and, being inverted a little, ſome of the elaſtic fluid is thrown out of it, which elaſtic fluid, paſſing through the hole, fills the meaſure. Then the receiver being replaced upon the ſhelf, the meaſure is drawn ſideway from over the hole, its braſs door is ſhut, and the meaſure being drawn from the ſhelf into the deeper water, is there turned upſide down, in order to expel that quantity of elaſtic fluid, which remains in the braſs piece; after which it is again inverted with the mouth downwards;—it is replaced upon the ſhelf, and its braſs door is drawn out.—Then the contained quantity of elaſtic fluid (which, proceeding conſtantly after the ſame manner, is always the ſame) may be thrown into the eudiometer-tube.

mediately after this operation the tube muſt be ſhook, by moving it alternately up and down in the water of the tub for about a quarter of a minute; then it is left a ſhort while at reſt, after which it is ſuſpended to the hook A B fig. 5th, plate III, ſo that the ſurface of the water within it may be about two inches above the water in the tub, and the braſs ſcale is ſlided upon it, till the upper edge of the lower ring coincides with the middlemoſt part of the ſurface of the water within the tube, and then is obſerved what diviſion of the ſcale coincides with any of the diviſions on the tube, by which means the quantity of elaſtic fluid remaining in the tube, may be clearly ſeen, to the hundredth part of a meaſure. This quantity, which ſhews the firſt diminution, is then ſet down in the following clear manner, viz. Firſt, the two meaſures of air introduced firſt into the tube are expreſſed by a Roman number, after which the one meaſure of nitrous air is expreſſed by another Roman number, and the meaſures, with the parts of a meaſure, remaining in the tube after the diminution, are expreſſed by common numbers with decimals; thus ſuppoſe, that after introducing two meaſures of common air and one of nitrous air, and after ſhaking &c. in the manner above directed, the quantity of elaſtic fluid remaining in the eudiometer is ſuch, that when the upper edge of the lower ring of the ſcale-piece coincides with the lower point of the ſurface of the water in the tube, the 56th diviſion of the ſcale falls againſt the ſecond circular diviſion on the tube, then this diminution is marked thus, II, I, 2,56, which ſignify, that two meaſures of common air, and one meaſure of nitrous air, after being diminiſhed by their mixing together, were reduced to two meaſures and fifty-ſix hundredth parts of a meaſure. Laſtly, after marking the firſt diminution, throw a ſecond meaſure of nitrous air into the tube, ſhake the inſtrument, and after a little reſt, as before, obſerve this ſecond diminution, which (ſuppoſing to have reduced the whole quantity of elaſtic fluid to three meaſures, more ſeven hundredth parts of a meaſure) is marked down in the memorandum-book thus, II, II, 3,07.

Sometimes one, or two, or three more meaſures of nitrous air muſt ſtill be added, in order to obſerve the diminution of ſome very pure ſpecies of reſpirable elaſtic fluid; but this will be mentioned occaſionally.

The diviſions, which begin from the upper ring of the ſcale-piece of the eudiometer, are uſeful, when the quantity of elaſtic fluid contained in it is ſo ſmall that the edge of the lower braſs ring cannot be raiſed ſo high as to coincide with the ſurface of the water within the tube, on account of the ſilk loop; in which caſe, the under edge of the upper ring is brought to that point, and then muſt be obſerved which of thoſe inverted diviſions coincides with the firſt circular diviſion upon the tube.

If it be aſked, why the two or more meaſures of nitrous air are not thrown into the tube all at once, and the laſt diminution noted? the anſwer is, that in this method the effects of ſimilar experiments have not been found to be ſo uniform as in the above-deſcribed way of proceeding.

In this manner the air of one time or place is compared with that of another time or place, and that is conſidered to be the pureſt of the two, or three, or more different kinds of air, which is diminiſhed the moſt by an equal and ſimilar mixture of nitrous air. Thus, ſuppoſe that the air of London, taken by emptying a bottle of water out of a window, and treated in the manner above-deſcribed, gives II, I, 2,13, and II, II, 3,01, and that the air of Briſtol, taken and treated in a like manner, gives II, I, 2,20, and II, II, 3,30, we conclude that the air of London is purer than that of Briſtol.—And ſo of the reſt.

In this operation care ſhoud be taken to perform the experiments always uniformly, viz. to ſhake the tube immediately after the nitrous air has been thrown into it; to leave it afterwards at reſt always for the ſame length of time, &c.; otherwiſe the reſults of ſimilar experiments are far from being alike. It is alſo neceſſary to obſerve, that by holding the meaſure, or the eudiometer-tube, with the hand, which is generally warmer than the water of the tub, the elaſtic fluid within the ſaid meaſure or tube may be often rarefied, ſo as to render the events of the experiment precarious, for which reaſon the ſaid inſtruments ſhould be held only with the extremities of the fingers and thumb; and before the door of the meaſure be ſhut, or the point of the ſcale upon the eudiometer-tube ometer-tube be fixed, thoſe inſtruments ſhould be left a ſhort time by themſelves, keeping the hands and breath ſufficiently far from them.

The nitrous air, although it may be procured from various ſubſtances, by means of the nitrous acid, yet it is proper for this experiment to make it with very pure quickſilver; a quarter of an ounce, or leſs, of which metal, with about an ounce of diluted nitrous acid, will produce a vaſt quantity of nitrous air, and which is always of the ſame quality, provided the quickſilver is always pure; whereas with other metals, as copper, braſs, &c. the nitrous air made at one time is often different from that made at another time, viz. it occaſions a greater or leſs diminution when mixed with common air of preciſely the ſame ſort.

This method the reader may eaſily conceive to be leſs exceptionable than any of thoſe mentioned above; and he may reſt aſſured, that if the purity of the ſame ſort of air be examined ſeveral times after this manner, the difference between one experiment and the other will ſeldom exceed one or two hundredth parts of a meaſure; however, that the ingenious experimentator may ſtill endeavour to contrive ſome other method of performing this moſt uſeful experiment, without obliging him to follow the methods adopted by others, I ſhall here ſubjoin the moſt neceſſary particulars, which, as far as it is known at preſent, are neceſſary to be kept in view concerning this operation.

I. When reſpirable air is mixed with nitrous air, their joint bulk is diminiſhed, and the diminution is greater when the air is purer, *cæteris paribus*, and contrarywiſe.

II. If a quantity of nitrous air be mixed with a quantity of reſpirable air, all at once, the diminution enſuing is greater than if the ſame quantity of nitrous air be added to the ſame quantity of reſpirable air at different times; from whence it follows, that the quicker the two ſorts of elaſtic fluids are mixed together, the greater is the diminution, and contrarywiſe.

III. Nitrous air of different quality occaſions a different degree of diminution with reſpirable air; hence care ſhould be taken to procure it from ſuch materials as are more uniform, and conſequently afford always nitrous air of the ſame quality.—Quickſilver, when very pure, anſwers exceedingly well for this purpoſe.

IV. The quality of nitrous air is impaired by keeping; eſpecially when in contact with water; for which reaſon it ſhould be made anew very often, as every other day, or every three days.

V. In performing the experiments with eudiometers, it ſhould be carefully remarked, that no miſtake ariſes from heat and cold; for the elaſtic fluids are eaſily contracted and dilated by the variation of temperature.

VI. Although the greateſt diminution takes place immediately after mixing the reſpirable and nitrous air together, eſpecially when they are agitated, yet they continue to diminiſh a little for ſome time after; for which reaſon the diminution ſhould be obſerved always at a certain time after mixing the two elaſtic fluids; and indeed it is abſolutely neceſſary to perform the whole proceſs always in a ſimilar manner, in order to obtain ſuch reſults as may be depended upon.

VI. In reſpect to the meaſure, it muſt be remarked, that the ſurface of the water, which lies contiguous to the ſurface of elaſtic fluid contained in a ſmall veſſel, is very far from being a flat plane, or from being always of the ſame figure even in the ſame veſſel, on account of the attraction or repulſion between the ſubſtance of the veſſel and the water, which is altered and impeded by the adheſion of extraneous bodies, and by ſeveral other circumſtances; hence it is very improper to uſe common open glaſs phials for this purpoſe. The drops of water adhering to the ſides of the veſſel, and the quality of the water in which the operation is performed, ſhould alſo be taken into conſideration.

VII. In caſe this experiment was to be performed in the courſe of ſome hours, in order to obſerve the laſt total diminution, or ſomething elſe that the operator may chooſe, then it will be proper to obſerve by a good barometer, if the gravity of the atmoſphere has ſuffered any change in the courſe of the experiment; for a remarkable alteration of the atmoſphere's preſſure may occaſion ſome difference in the reſult of the experiments.

VIII. Laſtly, it ſhould be remarked, that in this ſubject, as well as in any other mechanical operation, ſimple contrivances ſhould always be preferred to more complicated ones; even when the latter ſeem to have ſome advantage in point of accuracy over the former, provided it be not very remarkable. Complex inſtruments are not only expenſive, and ſubject to be eaſily put out of order, but they occaſion very frequent miſtakes, on account that the operator has generally many things to do, and to keep in proper order; in which caſes it is more eaſy to overſee or miſtake ſome of them.

We have already remarked, that if a receiver, inverted in water or other viſible fluid, is partly filled with that fluid and partly with air or other elaſtic fluid, the ſpace occupied by that elaſtic fluid is not the ſame as it would be in the open air, viz. where it is only acted upon by the uſual preſſure of the atmoſphere; for example, if a cubic inch of air, taken near the apparatus where the experiment is to be performed, is introduced into a long tube previouſly filled with and inverted in water, ſo that the ſurface of the water within the tube may be about twenty inches above the ſurface of the water in the baſin, then by accurate gauging, that quantity of air will be found to occupy a greater ſpace than one cubic inch, becauſe the preſſure of the atmoſphere, which keeps that quantity of air compreſſed, is, in this caſe, partly counteracted by the weight of the pillar of water in the tube. If, inſtead of water, the experiment be tried in quickſilver, which is ſo much heavier than water, the difference between the real and apparent ſpace occupied by a quantity of elaſtic fluid, &c. is very conſiderable. In order to avoid the error ariſing from this principle, which is exceedingly neceſſary in performing experiments of this ſort; the moſt expeditious method is to bring the receiver ſo low into the water or quickſilver, that the ſurface of the water or quickſilver within the receiver may be even with the ſurface of the water or quickſilver in the tub. But this method is ſometimes impracticable, eſpecially with quickſilver, in which caſe the above-mentioned error being more conſiderable, it is more neceſſary to be corrected; becauſe, when the pillar of mercury, or of water, in the tube, is longer than the depth of the ſame fluid in the tub, their ſurfaces, it is evident, cannot be brought to coincide with each other; in this caſe, we muſt have recourſe to calculation, in order *to deduce the real quantity of elaſtic fluid, from the apparent ſpace it occupies in a receiver, which is filled partly with it and partly with water or other viſible fluid.*

For this purpoſe, it muſt be remembered what was obſerved above, viz. that the ſpaces into which air or other elaſtic fluid is contracted, are to one another in the inverſe ratio of the preſſures which confine thoſe elaſtic fluids; conſequently the ſpace occupied by a quantity of elaſtic fluid A B, fig. 6. Plate III. confined in the tube A C, inverted in quickſilver, and filled with quickſilver as far as B, is to the ſpace which the ſame quantity of elaſtic fluid occupies out of the tube, as the preſſure which acts upon it when out of the tube, to the preſſure which acts upon it when in the tube; that is, as the height of the barometer to the ſame height of the barometer, leſs the perpendicular height B C of the quickſilver in the tube. Thus ſuppoſe that the length A B of the tube, occupied by an elaſtic fluid, is 3 inches, and that the length B C, filled with quickſilver, is 20 inches; it is required to determine the length of the ſame tube, which the ſame quantity of elaſtic fluid would occupy, if the ſurface of the quickſilver in the baſin was brought even with B; viz. if the ſaid elaſtic fluid was only acted upon by the preſſure of the atmoſphere.— Firſt obſerve the height of the barometer at that time, which ſuppoſe to be 30 inches; then ſay, as the height of the barometer is to the ſame height, leſs the height C B of the quickſilver in the inverted tube A B, ſo is the ſpace A B to the real ſpace required; that is $30 : 30 - 20 :: 3 : \frac{3 \times \overline{30 - 20}}{30} = 1$: ſo that one inch is the length of the tube A C, which the quantity of elaſtic fluid A B would occupy, if the ſurface B of the quickſilver in it, was brought even with that of the quickſilver in the baſin.

N. B. The tube A C is ſuppoſed to be perfectly cylindrical, otherwiſe the calculation muſt be adapted to the form of the veſſel, and then it would become very intricate.

As this eaſy calculation is neceſſary for the right performance of ſeveral experiments, I ſhall here expreſs it in a manner ſtill more eaſy and familiar, for the ſake of thoſe readers who are very little acquainted with arithmetic.

PROBLEM.

A cylindrical glaſs tube A C, fig. 6. Plate III. cloſed at A, and inverted in quickſilver, is filled with quickſilver as far as B, ſo that the perpendicular height B C, is equal to 8 inches; the remaining ſpace A B, (equal to 7 inches) contains elaſtic fluid. It is required to know the length A B of the tube, in which the elaſtic fluid would be confined, if the tube was put into the quickſilver ſo low, as that the ſurface B of the quickſilver in it, might coincide with the ſurface of the quickſilver in the baſin; given the barometrical height at that time (28 inches.)

RULE.

Subtract the height B C (8) from the given barometrical height (28); multiply the remainder (20) by A B (7); divide the product (140) by the barometrical height (28), and the quotient (5) is the anſwer required.

If the experiment be made in water inſtead of quickſilver, the calculation is the ſame, excepting only, that inſtead of 28 inches, which is the height of the mercurial barometer, we muſt take 14 times 28, which would be the height of a water barometer, for water is about 14 times lighter than quickſilver.

The inverſe of this problem, viz. from the given real quantity of elaſtic fluid, and given height of the quickſilver B C in the tube, to find the apparent length A B; is neither of great uſe nor ſo eaſily performed; I ſhall however ſubjoin it in the note, for the ſake of thoſe readers, who are converſant with algebraical calculations *.

In order to avoid the continual trouble of calculating, &c. I have here ſubjoined a table, by which the real quantity of elaſtic fluid contained in an inverted tube, partly filled with

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* Let a glaſs tube, 30 inches (*a*) long, be filled with quickſilver, excepting 8 inches (*b*); and let it be inverted in a baſin containing alſo quickſilver, ſo that the 8 inches of common air may riſe to the top: It is required to find at what height the quickſilver will remain ſuſpended; the barometrical height being at that time 28 inches (*d*).

In this experiment, the quickſilver that remains ſuſpended in the tube, together with the elaſtic force of the air in the top of it, being a counterbalance to the preſſure of the atmoſphere, may be expreſſed by the height of the barometer (*d*).

Put x for the inches of mercury in the tube, then the ſpace occupied by the air in the top of it, is $a—x$. It occupied formerly b inches, and its elaſtic force, or barometrical height, was d inches; therefore the force now muſt be $\left(a—x : b :: d : \right)\frac{bd}{a—x}$ inches. Therefore $x+\frac{bd}{a—x}=d$. This equation reduced, and putting $a+d=2m$, produces $x^2—2mx=bd—ad$; which equation reſolved gives $x=m\pm\sqrt{m^2+bd—ad}=44$, or 14. But one of the roots 44 is impoſſible to be true, for the quickſilver is never ſuſpended ſo high, even in a tube exhauſted of air; therefore the other root 14 is the true anſwer.

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Space occupied by the Elaſtic Fluid.

Space occupied by the Mercury.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.	39.	40.	
1.	0,96	1,92	2,88	3,84	4,80	5,76	6,72	7,69	8,66	9,64	10,6	11,56	12,52	13,48	14,44	15,4	16,36	17,33	18,33	19,32	20,28	21,24	22,2	23,16	24,12	25,08	26,04	27,0	27,96	29,0	29,96	30,92	31,88	32,84	33,8	34,76	35,72	36,68	37,64	38,6	1.
2.	0,93	1,86	2,79	3,72	4,65	5,58	6,51	7,44	8,37	9,31	10,24	11,17	12,1	13,03	13,96	14,89	15,82	16,75	17,68	18,62	19,55	20,48	21,41	22,34	23,27	24,2	25,13	26,06	27,0	27,97	28,9	29,83	30,76	31,69	32,62	33,55	34,48	35,4	36,34	37,26	2.
3.	0,90	1,8	2,68	3,57	4,46	5,37	6,27	7,16	8,05	8,98	9,97	10,86	11,75	12,64	13,53	14,42	15,31	16,2	17,08	17,95	18,85	19,75	20,65	21,55	22,45	23,35	24,25	25,15	26,05	26,95	27,85	28,75	29,65	30,55	31,45	32,32	33,23	34,13	35,03	35,91	3.
4.	0,87	1,73	2,59	3,45	4,31	5,17	6,03	6,9	7,77	8,65	9,51	10,37	11,23	12,1	12,95	13,81	14,67	15,54	16,41	17,28	18,14	19,0	19,86	20,72	21,58	22,45	23,32	24,19	25,05	25,93	26,79	27,65	28,51	29,37	30,23	31,09	31,96	32,83	33,7	34,56	4.
5.	0,84	1,67	2,50	3,33	4,16	4,99	5,82	6,65	7,48	8,32	9,15	9,98	10,81	11,64	12,47	13,27	14,1	14,93	15,77	16,61	17,44	18,27	19,1	19,93	20,76	21,59	22,42	23,25	24,08	24,91	25,74	26,57	27,40	28,23	29,06	29.89	30,72	31,55	32,38	33,21	5.
6.	0,81	1,61	2,41	3,21	4,01	4,81	5,60	6,4	7,2	7,97	8,77	9,57	10,36	11,16	11,96	12,75	13,55	14,34	15,13	15,91	16,71	17,51	18,31	19,11	19,91	20,71	21,51	22,31	23,11	23,91	24,7	25,49	26,28	27,08	27,87	28,66	29,45	30,24	31,04	31,83	6.
7.	0,78	1,54	2,3	3,06	3,82	4,58	5,34	6,1	6,86	7,63	8,39	9,15	9,91	10,67	11,43	12,19	12,95	13,71	14,47	15,23	16,0	16,76	17,52	18,28	19,04	19,81	20,58	21,34	22,11	22,89	23,65	24,41	25,17	25,93	26,69	27,45	28,21	28,97	29,73	30,49	7.
8.	0,74	1,47	2,2	2,93	3,66	4,39	5,12	5,84	6,57	7,29	8,02	8,75	9,48	10,21	10,94	11,67	12,4	13,12	13,84	14,56	15,29	16,02	16,75	17,48	18,21	18,94	19,67	20,4	21,13	21,87	22,60	23,33	24,06	24,79	25,52	26,25	26,98	27,7	28,42	29,14	8.
9.	0,70	1,39	2,08	2,77	3,46	4,15	4,85	5,54	6,24	6,95	7,64	8,33	9,02	9,71	10,4	11,1	11,79	12,49	13,19	13,89	14,58	15,27	15,96	16,65	17,35	18,05	18,74	19,44	20,13	20,85	21,54	22,23	22,92	23,61	24,31	25,0	25,68	26,37	27,06	27,79	9.
10.	0,66	1,32	1,98	2,64	3,3	3,96	4,62	5,28	5,94	6,61	7,27	7,93	8,60	9,25	9,91	10,57	11,23	11,89	12,55	13,22	13,88	14,54	15,2	15,86	16,52	17,18	17,84	18,5	19,16	19,83	20,49	21,15	21,81	22,47	23,13	23,79	24,45	25,11	25,77	26,44	10.
11.	0,62	1,24	1,87	2,49	3,12	3,74	4,36	4,98	5,61	6,27	6,89	7,52	8,14	8,77	9,39	10,02	10,64	11,27	11,89	12,51	13,13	13,76	14,38	15,01	15,64	16,27	16,9	17,53	18,17	18,81	19,43	20,06	20,68	21,31	21,93	22,56	23,18	23,81	24,43	25,08	11.
12.	0,58	1,18	1,78	2,38	2,98	3,58	4,18	4,78	5,38	5,95	6,55	7,15	7,75	8,35	8,95	9,55	10,15	10,7	11,3	11,8	12,4	13,0	13,6	14,2	14,8	15,4	16,0	16,6	17,2	17,8	18,4	19,0	19,6	20,2	20,8	21,4	22,0	22,6	23,2	23,72	12.
13.	0,54	1,09	1,64	2,19	2,74	3,29	3,84	4,39	4,94	5,6	6,15	6,71	7,27	7,83	8,38	8,95	9,5	10,06	10,62	11,18	11,74	12,3	12,86	13,42	13,98	14,54	15,1	15,66	16,22	16,78	17,34	17,9	18,46	19,02	19,58	20,14	20,7	2,26	21,81	22,36	13.
14.	0,51	1,03	1,55	2,07	2,6	3,12	3,65	4,17	4,7	5,25	1,77	6,3	6,82	7,35	7,87	8,4	8,92	9,45	9,96	10,5	11,02	11,54	12,06	12,58	13,12	13,65	14,17	14,7	15,22	15,76	16,28	16,8	17,33	17,85	18,38	18,91	19,43	19,94	20,48	21,01	14.
15.	0,47	0,97	1,47	1,96	2,45	2,95	3,44	3,93	4,42	4,91	5,4	5,89	6,38	6,87	7,36	7,85	8,34	8,84	9,33	9,83	10,32	10,81	11,3	11,79	12,28	12,77	13,26	13,75	14,24	14,74	15,23	15,72	16,11	16,61	17,11	17,6	18,1	18,6	19,1	19,6	15.
16.	0,43	0,89	1,35	1,81	2,27	2,73	13,19	3,65	4,11	4,58	5,03	5,49	5,95	6,4	6,86	7,32	7,78	8,23	8,69	9,15	9,61	10,07	10,53	11,0	11,45	11,91	12,37	12,83	13,29	13,73	14,18	14,63	15,08	15,53	15,98	16,43	16,88	17,33	17,78	18,24	16.
17.	0,40	0,82	1,25	1,67	2,1	2,52	2,95	3,37	3,8	4,24	4,66	5,09	5,51	5,94	6,36	6,79	7,21	7,63	8,05	8,47	8,9	9,33	9,75	10,18	10,6	11,03	11,45	11,87	12,29	12,73	13,14	13,56	13,97	14,39	14,81	15,22	15,64	16,05	16,47	16,89	17.
18.	0,36	0,75	1,14	1,53	1,92	2,31	2,70	3,1	3,5	3,9	4,29	4,68	5,07	5,46	5,85	6,24	6,63	7,02	7,41	7,79	8,18	8,57	8,96	9,35	9,74	10,13	10,52	10,92	11,32	11,72	12,11	12,5	12,89	13,28	13,67	14,06	14.46	14,85	15,24	15,54	18.
19.	0,33	0,69	1,05	1,41	1,77	2,13	2,49	2,85	3,21	3,56	3,92	4,28	4,64	5,1	5,35	5,7	6,06	6,41	6,76	7,11	7,57	7,83	8,19	8,55	8,91	9,27	9,63	10,0	10,35	10,71	11,06	11,41	11,76	12,11	12,46	12,81	13,16	13,51	13,86	14,19	19.
20	0,30	0,62	0,94	1,26	1,59	1,91	2,23	2,56	2,89	3,22	3,54	3,86	4,18	4,5	4,82	5,14	5,46	5,78	6,11	6,44	6,76	7,10	7,41	7,74	8,06	8,38	8,7	9,03	9,38	9,7	10,02	10,34	10,66	10,98	11,30	11,60	11,92	12,23	12,54	12,84	20.
21.	0,27	0,55	0,84	1,12	1,42	1,7	2,0	2,3	2,60	2,88	3,17	3,45	3,74	4,03	4,32	4,6	4,9	5,18	5,47	5,76	6,05	6,34	6,63	6,92	7,21	7,50	7,8	8,08	8,37	8,66	8,94	9,22	9,5	9,78	10,06	10,35	10,64	10,93	11,22	11,49	21.
22.	0,24	0,49	0,74	1,0	1,26	1,51	1,76	2,02	2,28	2,54	2,8	3,05	3,30	3,56	3,81	4,06	4,31	4,57	4,82	5,08	5,33	5,58	5,84	6,10	6,35	6,6	6,86	7,11	7,37	7,64	7,89	8,14	8,4	8,64	8,9	9,14	9,4	9,65	9,90	10,14	22.
23.	0,21	0,43	0,65	0,87	1,09	1,31	1,53	1,75	1,97	2,20	2,42	2,64	2,86	3,08	3,30	3,52	3,74	3,96	4,18	4,4	4,62	4,84	5,06	5,28	5,5	5,72	5,94	6,16	6,39	6,62	6,84	7,06	7,28	7,5	7,72	7,94	8,16	8,36	8,6	8,79	23.
24.	0,18	0,36	0,54	0,72	0,91	1,1	1,3	1,48	1,67	1,86	2,04	2,23	2,42	2,6	2,8	2,97	3,16	3,36	3,54	3,72	3,9	4,1	4,28	4,47	4,66	4,84	5,04	5,22	5,41	5,6	5,78	5,97	6,15	6,34	6,52	6,7	6,89	7,07	7,26	7,44	24.
25.	0,15	0,3	0,45	0,6	0,75	0,9	1,05	1,21	1,36	1,52	1,67	1,82	1,97	2,12	2,27	2,42	2,58	2,74	2,9	3,05	3,2	3,35	3,5	3,65	3,8	3,95	4,1	4,27	4,43	4,58	4,73	4,88	5,03	5,18	5,33	5,48	5,63	5,78	5,93	6,09	25.
26.	0,12	0,24	0,36	0,48	0,6	0,72	0,84	0,96	1,08	1,18	1,3	1,42	1,54	1,66	1,78	1,9	2,02	2,14	2,26	2,37	2,5	2,61	2,73	2,85	2,97	3,1	3,21	3,33	3,45	3,56	3,68	3,8	3,92	4,04	4,16	4,28	4,4	4,52	4,63	4,74	26.

it and partly with quickſilver, may be found by inſpection, when the apparent place A B, fig. 6. Plate III. occupied by the elaſtic fluid, and the height of the quickſilver B C, are known. Thus ſuppoſe that the ſpace A B is 10 inches, and B C is 8; find the number 10 in the upper row of numbers in the table, and deſcending along that column, which is immediately under it, ſtop when you come juſt oppoſite to No. 8, in the firſt lateral row of numbers, and in that corner you will find the anſwer, viz. 7 inches and 29 hundredths of an inch.

N. B. This table is calculated upon a mean barometrical height, i. e. 29 $\frac{1}{2}$ inches; hence it cannot be uſeful at all times, for very accurate experiments; in which caſes recourſe muſt be had to the above-mentioned calculation.

CHAP. VII.

Practical rules concerning the uſe of the apparatus, and the performing of experiments.

IN performing experiments relative to this branch of philoſophy, in which acids, alkalies, fire, metals, noxious fluids, &c. are to be continually uſed; it is natural to ſuppoſe, that the greateſt poſſible precaution is neceſſary, in order to avoid miſtakes and damages; for which reaſon it ſeems proper to collect into this chapter, ſome general rules, and to point out thoſe caſes and operations in which the unexperienced beginner may be more liable to err. Experiments relating to other ſubjects, as optics, electricity, &c. although liable to be miſtaken, yet can ſeldom produce any dangerous effect; but the errors which happen in performing experiments on the ſubject of this work, may be productive of the moſt ſerious conſequences.

Care ſhould be had to keep the mineral acids in thoſe places in which the bottles containing them are leſs ſubject to be broken, and if broken, may occaſion the leaſt damage poſſible. The beſt method is, to keep thoſe bottles in ſmall baſins of white earthen ware. Without being obliged to handle continually a large bottle of acid, it is very convenient to have ſmall bottles filled with the different acids, which are more eaſily managed, and when empty may be filled again out of the large ones. In pouring out the acid, the laſt drop which remains upon the edge of the phial ſhould either be prevented from running down, by a little attention, or it ſhould be wiped off; otherwiſe, when the hand is applied again to the ſame bottle, the acid will adhere to the ſkin, &c.

When glaſs veſſels are filled with water, in order to fill them afterwards with ſome elaſtic fluid, it is neceſſary to allow a little time for the ſmall bubbles of air to aſcend to the top of the water and to break, before the veſſel be inverted; otherwiſe, if the veſſel be inverted immediately after being filled with water, thoſe minute bubbles will gradually collect together, ſo as to form a conſiderable quantity of air at the top of the veſſel, which, mixing with the elaſtic fluid that is afterwards introduced, may render the reſult of ſome experiments precarious.—This caution is highly neceſſary when experiments are performed with eudiometers.

When the materials which are to produce any elaſtic fluid are put into the proper phial, with the crooked tube, as deſcribed in the preceding pages, part of the phial remains filled with common air; hence the firſt quantity of factitious elaſtic fluid, which comes out of the ſaid phial through its tube, is mixed with that common air; for which reaſon it muſt not be received into the veſſel filled with and inverted in the water for that purpoſe: but as it is difficult to judge of the quantity of elaſtic fluid which comes out of the crooked tube of the phial, and conſequently ſometimes more than neceſſary may be waſted; the moſt proper method is, to receive the firſt produce of elaſtic fluid in a ſmall inverted receiver, merely to judge of its quantity; which, as ſoon as it ſeems to be equivalent to the ſpace left filled with air in the phial, may be thrown away, by turning that ſmall receiver with the mouth upwards; and at the ſame time the mouth of the bent tube of the phial is brought under the large inverted receiver, into which the elaſtic fluid, &c. is deſigned to be received.

As it is often neceſſary to apply the flame of a candle, or a ſmall pan with charcoal, under the phials that contain the materials which are to produce the elaſtic fluids, the experimentator ſhould remember, that when the operation is required to be diſcontinued, it is neceſſary to remove firſt the extremity of the bent tube from the water or quickſilver, and then to remove the candle or fire from under the phial; for if the candle is taken away whilſt the end of the tube is ſtill under water, the water will immediately ruſh into the phial, and generally break it.

Thoſe phials, containing the effervеſcing materials for the production of elaſtic fluids, ſometimes are broken whilſt they are in uſe, and in that caſe the contents are ſcattered about the floor, and other bodies near; for which reaſon it is adviſable to keep a baſin upon the floor, juſt under thoſe phials, whilſt they are in actual uſe.

After making nitrous air, the ſolution of quickſilver (in caſe that metal be uſed) in nitrous acid, inſtead of being thrown away, may be put in a particular veſſel, where a conſiderable quantity of it being accumulated, the quickſilver may be obtained again from it, by diſtillation made in a proper manner.

The room wherein thoſe experiments are performed ſhould have windows eaſy to be opened; for ſometimes receivers, containing noxious elaſtic fluids, are overturned or broken, in which caſe thoſe elaſtic fluids infect the air of the room, and are pernicious to the health of the operator, if they are not quickly expelled by ventilation.

When a receiver containing ſome elaſtic fluid is inverted in quickſilver, and is required to be tranſported into the tub of water; it muſt be firſt put into a ſmall cup or baſin full of quickſilver, and then, being removed from the box of quickſilver and tranſported into the tub of water, the whole cup, together with the lower part of the receiver, muſt be plunged into the water, wherein the receiver being kept ſteady, the cup is ſlipped from under it, &c.—In this operation it often happens that ſome quickſilver falls to the bottom of the water-tub. This is of no conſequence whatever; for the quickſilver is recovered the firſt time that the water of the tub is changed. The difficulty conſiſts in tranſporting the elaſtic fluid, contained in a receiver inverted in water, from the water tub into the box or baſin of quickſilver. For this purpoſe, the elaſtic fluid muſt be put firſt into a receiver of ſuch ſize as may be entirely filled by it, ſo that hardly any water remains in it; ſecondly, this receiver muſt be put into a cup or ſmall baſin full of water, and thus muſt be tranſported into the quickſilver box, after the above-mentioned manner of tranſporting the receiver from the quickſilver into the water-tub; but when the receiver has been thus brought into the quickſilver, a ſmall quantity of water always remains in it, which muſt be removed, otherwiſe the purpoſe of doing this operation would not be anſwered, as its intention is to remove that elaſtic fluid from the contact of water. In order to that, fill another dry receiver with, and invert it in quickſilver, to the mouth of which adapt a doubled linen rag, which with the fingers of one hand muſt be kept ſo as to be concave towards the cavity of the receiver; then the other receiver, containing the elaſtic fluid, muſt be inclined, ſo that the contained elaſtic fluid coming out of it, may paſs into the other receiver through the linen rag, which muſt be previouſly pierced with ſeveral holes as big as a crow-quill. In this manner the elaſtic fluid paſſes into the other receiver pretty free from the water, which will be imbibed by the rag. The difficulty of this operation can hardly be imagined by thoſe who have never tried it; the weight of the quickſilver, the ſize of its baſin or box, which is generally ſmall, and ſeveral other circumſtances, offer obſtacles, which cannot be overcome without great practice.

There are ſeveral other precautions, and methods of operating, which might be mentioned, for the inſtruction of the unexperienced beginner; but this ſeems rather needleſs, ſince practice will eaſily ſuggeſt them; I ſhall therefore conclude this Part of my work, with only reminding my reader, who is deſirous to perform the experiments here mentioned, that in the beginning he will hardly ſucceed, even in the eaſieſt operations, but that gradually he will become more expert, and, as it may be ſaid, ſucceſsful; for which reaſon he ſhould not condemn ſome of the experiments, hereafter to be mentioned, as falſe, becauſe they do not ſucceed with him exactly as they are deſcribed; but he ſhould defer his judgment till after ſeveral repeated trials, and even after conſulting thoſe perſons, who, being acquainted with the ſubject, may either point out the cauſe of his miſtake, or ſuggeſt to him ſome new way of trying the queſtioned fact.

PART III.

Of the Nature and Properties of Air, and other permanently elaſtic Fluids.

IN the preceding Part we treated of the more general properties of air, and other permanently elaſtic fluids, and alſo deſcribed the apparatus, which, in the preſent advanced ſtate of the ſubject, is neceſſary to perform experiments thereon, together with the principles upon which it depends. This diſpoſition has been intended to anſwer two purpoſes; to wit, that of rendering the preſent Part more ſuccinct and perſpicuous; and that of inſtructing the beginners in the more elementary parts of the ſubject, before they enter into the more abſtruſe inveſtigations of its objects; whilſt, at the ſame time, thoſe who are previouſly acquainted with the principles, will not be obliged to read them over again; as it would be neceſſary, in caſe they were intermixed together with the other properties of elaſtic fluids.

My reader, therefore, whom I muſt ſuppoſe already acquainted with the ſubject of the preceding Part; muſt not expect to find in the following pages a minute detail of the experiments neceſſary to prove the properties that are to be mentioned; it will be ſufficient, for inſtance, to ſay, that ſuch a mixture of elaſtic fluids is inflammable or not inflammable, without deſcribing the manner of inflaming it; that ſuch materials put together will produce a particular ſort of elaſtic fluids, without adding that they muſt be introduced into a phial with a bent tube, &c.: for theſe operations have already been deſcribed under general and diſtinct heads. There are, indeed, many experiments which muſt be conducted in a manner different from the general way of operating, and ſeveral operations which are not comprehended amongſt thoſe already deſcribed; but theſe will be particularly mentioned in proper places.

CHAP. I.

Of the nature and properties of air.

THE inviſible elaſtic fluid, which encompaſſeth the earth, and is commonly called *Air*, in its uſual ſtate is combined with innumerable ſubſtances, which are foreign to its conſtitution; for when deprived of thoſe extraneous bodies, it is ſtill elaſtic air, fit for the various proceſſes to which it is neceſſarily ſubſervient. Water and ſome ſaline bodies are the viſible ſubſtances that are mixed with the air of almoſt every place about the earth, viz. they are viſible when ſeparated from the air; but in particular ſituations the air is impregnated with various other bodies, as ſulphur, putrid effluvia, and the like, which are the emanations of particular ſoils, of vulcanos, putrid marſhes, &c. Earthy particles, alſo, may be ſaid to be ſometimes combined with air; or at leaſt they float in it, ſo as to be kept up for a conſiderable time, and ſo ſubdivided as to be inviſible. Indeed there are ſeveral bodies, of which it is difficult to ſay whether they are really combined with the aereal particles, or are merely ſuſpended in that fluid, in conſequence of their being of the ſame ſpecific gravity *.

It is certain that water is chymically combined with air. Its preſence in that elaſtic fluid is manifeſted by the drops of water, which adhere to the outſide ſurface of veſſels containing any ſubſtance conſiderably colder than the circumambient air; by the deliqueſcence of ſeveral dry ſalts; by the water which oil of vitriol and various ſalts imbibe when expoſed to the open air; and by thoſe inſtruments called *hygrometers*, or

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* The difference between combination and ſuſpenſion of one ſubſtance in another, is, that in the former, the particles of the bodies attract each other, in virtue of which attraction, even bodies of different ſpecific gravities, as water and vitriolic acid, are intimately incorporated with each other; but in the latter the ſuſpenſion or mixture is merely mechanical.

hygroſcopes,

hygroſcopes, which are purpoſely made to ſhew the degree of moiſture of the atmoſphere †; and by various other means.

That thoſe two bodies, viz. water and air, do really combine with each other, is eaſily deduced from the following conſiderations:—Water is kept in the ſtate of vapour, or of an elaſtic fluid, by a degree of heat equivalent to the 212th of FARENHEIT's thermometer.—In a temperature colder than that, the vapour becomes again water; from whence it ſeems to follow, that whenever water evaporates, or is ſuſpended in air, their temperature being leſs than the 212th degree of FARENHEIT's thermometer, it muſt be evaporated or ſuſpended, by virtue of their mutual attraction; viz. muſt be combined together.

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† It is a vulgar error to ſuppoſe that hygrometers ſhew the quantity of water combined with the air; for they indicate only the quantity of water which cannot be combined with the air; or (in chymical phraſeology) that quantity of water which is precipitated from the air. Thus, for inſtance, if a certain quantity of water is combined with a quantity of air, whatever their proportion may be, the hygrometers expoſed to it are not in the leaſt affected by that quantity of water; but if by the acceſſion of cold, or by other means, the water is ſeparated from the air, then the hygrometer is affected by it, and the degree of moiſture it indicates, is in proportion to the quantity of water that is ſeparated from the air in a given time; hence, when the hygrometer indicates *very dry*, it does not follow that there is no water, or very little of it, mixed with the air; but that the water, whatever its quantity may be, is ſo well combined with the air, that none of it is actually ſeparated from that permanently elaſtic fluid. This truth may be clearly proved, by the following eaſy experiment:—Introduce an hygrometer of any conſtruction, provided it be pretty ſenſible, into a large glaſs bottle, containing only common air, which bottle let be ſtopped, ſo that the outward air may not communicate with the air within it. Then let the bottle be brought into a cold place, or let any freezing mixture be put round it, and you will perceive, that on the acceſſion of cold, the index of the hygrometer immediately moves towards *moiſt*, becauſe cold air cannot keep as much water diſſolved as when it is hot; but if then the apparatus, being removed from the cold, be brought in a warmer place, the index of the hygrometer will move towards *dry*.

Heat, which increaſes the repulſion between the particles of water and of air, increaſes their mutual attraction; thus hot air keeps diſſolved more water than when cold; and if hot air be cooled, it depoſits, as we obſerved in the preceding note, ſome of the water which it kept diſſolved; the parts of which water, uniting with each other, form an aggregate of viſible corpuſcles or clouds, which are not combined, but float in the air, and do not fall from it till they are formed into more compact and heavier parcels, called *drops*. It is difficult to comprehend how the particles of water, which are collected together becauſe the air cannot keep them diſſolved, ſhould want power to collect themſelves into heavy drops and fall downwards, rather than remain ſuſpended, for a conſiderable time, in the form of vapour or clouds, in thoſe regions of the atmoſphere, which, rather than being very hot, are generally colder than the ſurface of the earth. It ſeems as if the particles of water in that ſtate, were actuated by two powers; to wit, their own attraction towards each other, and ſome other power, which prevented their coming ſo near as to be formed into water; but what that other power is, and how it acts, is ſtill a myſtery. If electricity was known to be the conſtant attendant of clouds and fogs, perhaps a very probable hypotheſis might, in that caſe, be formed; but ſince

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the atmoſpherico-electrical experiments, hitherto made, don't ſhew the certainty of the fact; this intereſting point of meteorology cannot at preſent be explained upon electrical principles.

In the greateſt degree of natural or artificial cold that has been ever tried, particles of water may be ſeparated from the air, either by the application of a greater degree of cold, or by expoſing to it thoſe ſubſtances, which abſorb the aqueous particles very readily; hence we deduce, that ſome quantity of water is always combined with air, and we are not acquainted with any means by which a quantity of air may be deprived of all the aqueous particles that are combined with it.

The quantity of water kept diſſolved by a given quantity of air of a certain temperature, I do not find that it has been yet determined; nor does it ſeem very eaſy to be aſcertained; ſince not only different degrees of heat, but alſo different degrees of preſſure, and probably ſome other cauſes, concur to alter it; beſides our preſent ignorance of a method of depriving air intirely of the water it contains, and of diſtinguiſhing when it is in that ſtate.

The ſmall quantity of ſaline matter, which may be obtained by evaporating rain-water, or which adheres to ſome bodies expoſed to the air for a long time, may perhaps be raiſed into the atmoſphere together with the vapours; or it may be attributed to the particles of earth that continually float in the air; or may even be raiſed by themſelves, in caſe of agitation, heat, or mutual attraction with the particles of air. Their uſual quantity is very ſmall, and the experiments, hitherto made, have not yet aſcertained any thing relating to their origin and ſtate of exiſtence.

As for the ſulphurous vapours, particular ſaline bodies, putrid and other effluvia, that are often mixed with the air, they are certainly accidental. They owe their origin to particular ſtates of the earth, and, according to their different natures, alter the effect of the air in thoſe proceſſes in which it is moſt eſſentially uſed. Thus, from being inſipid, and inodorous, it becomes nauſeous and diſagreeable by ſulphurous emanations; it becomes poiſonous by the fumes of arſenic; it becomes peſtilential by putrid effluvia, &c. Thoſe foreign ſubſtances, which, by mixing with the air, thus alter its effects upon animal and other bodies, ſometimes are of ſuch nature, that they will ſoon ſubſide, like duſt, and leave the air as pure as before; whilſt others are not ſo ſlightly mixed with it as to be afterwards ſeparated very eaſily; but either continue always in their mixt ſtate with the air, or abandon it after a very long time.

The inviſible ſubſtance, which combines with air more eaſily, and by its combination alters remarkably the nature of that elaſtic fluid, is the inflammable principle or phlogiſton. In all thoſe proceſſes called phlogiſtic, in which the inflammable principle eſcapes from bodies, as in reſpiration, combuſtion, putrefaction, diſſolution, &c. (excepting when the phlogiſton, ſeparated from one body, is forced into ſome other bodies, in places defended from the air, as in the reduction of metallic calxes) the air does readily combine with it, and thence becomes *phlogiſticated.* In ſhort, the air aſſiſts reſpiration, combuſtion, and other phlogiſtic proceſſes, inſomuch as it readily unites with the inflammable principle, diſcharged in ſuch proceſſes. But this combination is limited; for according as more and more phlogiſton is combined with the air, its capacity of abſorbing more phlogiſton decreaſes, and at laſt ceaſes; in which ſtate the air is ſaid to be *compleatly phlogiſticated*, viz. to have acquired as much phlogiſton as is it poſſibly can; and then it becomes quite unfit for reſpiration, combuſtion, or, in ſhort, for any phlogiſtic proceſs.

If no other ſort of air purer than common atmoſpheric air had been known, we might probably conſider the air of ſome uninhabited countries, or at the tops of ſome mountains, as containing little or no phlogiſton; but the diſcovery of a ſort of permanently elaſtic fluid, commonly called dephlogiſticated air, which is incomparably ſuperior to common air, in reſpect to its aſſiſting reſpiration, combuſtion, and any other phlogiſtic proceſs, ſhews, that the atmoſpheric air, even the pureſt that can be found, contains a conſiderable ſhare of phlogiſton; viz. is in great meaſure phlogiſticated.

It may therefore be concluded, that every portion of atmoſpheric air, that falls under our obſervation, is not a pure homogeneous body, but that it is certainly combined with phlogiſton and water, beſides the poſſibility, and, as will appear by the following pages, the ſtrong probability, of its containing ſeveral other bodies.

That the air, which is impregnated with watery particles, ſhould be ſtill fit for reſpiration, combuſtion, &c. whereas if impregnated with phlogiſton, it becomes incapable to aſſiſt thóſe proceſſes; and that phlogiſticated air ſhould be fit to aſſiſt the evaporation of water, ſeems myſterious to ſome perſons; but the difficulty will ſoon vaniſh, if it be conſidered, that the air is capable of combining with both thoſe, and even with more ſubſtances beſides; and that it is its incapacity of combining with more than a limited quantity of each body, that renders it unfit to aſſiſt thoſe proceſſes, in which that particular body is diſcharged, beyond a certain degree. Thus air, impregnated with as much phlogiſton as it can, is unfit for the proceſs of combuſtion, of reſpiration, and other phlogiſtic proceſſes, becauſe no more phlogiſton can be combined with it; but then it does not follow, that this ſame air cannot abſorb any water, viz. that it cannot aſſiſt the evaporation of water; and, on the contrary, air, which has imbibed as much water as it poſſibly can, is no longer capable to aſſiſt the evaporation of water, but it is ſtill in a ſtate proper to abſorb phlogiſton, viz. of aſſiſting phlogiſtic proceſſes. The ſame thing may be ſaid about the air's property of mixing with ſome other ſubſtances.

The attentive reader muſt have remarked, that in the preceding lines, reſpiration has been conſidered as a phlogiſtic proceſs, without regarding the opinions contrary to that aſſertion. The reaſon is, that this propoſition ſeems at preſent to be grounded upon indiſputable principles; of which, however, it is now neceſſary to take particular notice; it being a ſubject of great conſequence to mankind.

An animal, as a dog, a pigeon, &c. being included in a cloſe receiver of a moderate capacity, lives but for a certain time, which is nearly proportionate to the quantity of air contained in the receiver; after which, death puts an end to the anxiety and pains, which the animal began to ſuffer ſince the air became ſufficiently depraved, and rendered unfit for eaſy and natural reſpiration. If another animal is introduced into the ſame quantity of depraved air, it dies preſently. This is a phenomenon obſervable with all thoſe animals which are obliged to maintain life by means of reſpiration. The ancients, as late as the laſt age, being very well acquainted with this remarkable property of the air, endeavoured to explain it various ways; but it is not neceſſary to detain my reader with a confutation, or even with a particular account of them at preſent, ſince this matter has been of late ſo well elucidated by the indefatigable Dr. PRIESTLEY, that its preſent theory can hardly be doubted even by the moſt ſceptic philoſopher*. The Doctor's explanation, in ſhort, is, that when the air is in the lungs, it acquires a quantity of phlogiſton from the blood, which diſcharge of phlogiſton is abſolutely neceſſary for the continuation of animal life; that in proportion as the air acquires more and more phlogiſton, its capacity of combining with that ſubſtance is leſſened, and at laſt vaniſhes; conſequently, the animal confined in a limited quantity of air, periſhes when that element is ſuffi-

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* Air was conſidered to be one of the aliments of the body by the old phyſician HIPPOCRATES; though it was more commonly believed that the air ſerved to temper the heat of the blood, acquired by a kind of vital fire, which was thought to be kept up in the heart; and that the office of the lungs was principally

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pally to carry off the ſmoke or vapours proceeding from that fire. It was alſo ſuppoſed by later philoſophers, that either the air itſelf, or ſome etherial or vital principle extracted from it, was introduced into the blood. Dr. MAYOW, whoſe works were printed at Oxford, in the year 1674, aſſerts that ſome nitre, or aereal ſpirit of nitre, enters the body through the lungs, and furniſhes the animal ſpirits, together with the heat that is communicated to the blood. It has been ſuppoſed, alſo, that the lungs ſerve to attenuate the blood, and to mix thoroughly together its different particles. On the contrary, others have ſuſpected that the blood is rather condenſed than attenuated in the lungs. It has been ſuppoſed by Dr. WHYTE, that ſome ſtimulating quality of the air was neceſſary to keep the heart in motion. See HALLER's Works Vol. iii.—Air has been conſidered even as an alkaly, or an acid, which was neceſſary to neutralize ſome ſuch principle abounding in the living body. HALLER ſuppoſes that the air loſes its ſpring in the lungs, in conſequence of which they collapſe, &c: he alſo ſuppoſes that ſome ſubſtances, miſcible with water, are taken into the body through that vehicle. Mr. CIGNA, an ingenious philoſopher of Turin, ſuppoſes, that the principal uſe of the air in the blood, is to counterbalance the preſſure of the external air. The late Mr. HEWSON, well known for his anatomical knowledge, as alſo for his work entitled *Experimental Inquiry into the Properties of the Blood*, having obſerved that the blood had a more florid red colour in the left auricle of the heart, than it had in the right, goes ſo far as to ſay, that as the change of the colour of the blood out of the body is occaſioned by the air, it might be preſumed, that the ſame change within the body was occaſioned alſo by air, and that this change took place in the lungs; though he acknowledged that it was ſtill unknown how this effect might be produced. See HEWSON's Exper. Inq. p. 9.

ciently phlogiſticated, becauſe the uſual and neceſſary diſcharge of phlogiſton from his lungs is intercepted.—The elegant ſimplicity of this doctrine, and its analogy with other known proceſſes of nature, is ſufficient to recommend it to the learned, even when its direct experimental proofs were wanting; but the experiments, that will be mentioned in the ſequel, are more than ſufficient to demonſtrate it. "That "reſpiration," ſays Dr. Priestley, "however, is in reality, "a true phlogiſtic proceſs, cannot, I think, admit of a doubt, "after its being found, that the air which has ſerved for this "purpoſe is left in preciſely the ſame ſtate as that which has "been expoſed to any other phlogiſtic proceſs. And ſince "all the blood in the body paſſes through the lungs, and, "according to Mr. Hewson's obſervations, and others, the "remarkable change between the colour of the venal and the "arterial blood takes place there, it can hardly be doubted, "that it is by means of the *blood* that the air becomes phlo"giſticated in paſſing through the lungs: and therefore, that "one great uſe of the blood muſt be to diſcharge the phlo"giſton with which the animal ſyſtem abounds, imbibing it "in the courſe of its circulation, and imparting it to the air, "with which it is nearly brought into contact, in the lungs; "the air thus acting as the great menſtruum for this "purpoſe."

"Though I had no doubt concerning this concluſion "from my former experiments, I thought ſo great a problem "deſerved as much illuſtration as could be given to it; and

" therefore I was willing to try, whether the blood was of " ſuch a nature, as to retain any of this power of affecting air, " when congealed, and out of the body, that it has when it " is fluid, and in the body; and the experiments have fully " anſwered my expectations.

" Having taken the blood of a ſheep, and let it ſtand till " it was coagulated, and the ſerum was ſeparated from it " (after which the ſurface, being expoſed to the common air, " is well known to aſſume a florid red colour, while the inſide is of a much darker red, bordering upon black) I " introduced pieces of the craſſamentum, contained in nets " of open gauze, or of wire, ſometimes through water, and " ſometimes through quickſilver, into different kinds of air, " and always found that the blackeſt parts aſſumed a florid " red colour in common air, and more eſpecially in dephlogiſticated air, which is purer and more fit for reſpiration " than common air (and accordingly the blood always acquired " a more florid colour, and the change was produced in leſs " time in this than in common air) whereas the brighteſt red " blood became preſently black in any kind of air that was " unfit for reſpiration, as in fixed air, inflammable air, nitrous " air, or phlogiſticated air; and after becoming black in the " laſt of theſe kinds of air, it regained its red colour upon being " again expoſed to common air, or dephlogiſticated air; the " ſame pieces becoming alternately black and red, by being " transferred from phlogiſticated to dephlogiſticated air; and " *vice verſa*.

" In theſe experiments the blood muſt have parted with

" its phlogiſton to the common air, or dephlogiſticated air,
" and have imbibed it, and have become ſaturated with
" it, when expoſed to phlogiſticated, nitrous, inflammable,
" or fixed air *."

The Doctor having clearly aſcertained, that the colour of the blood is changed according to the quality of the permanently elaſtic fluid, to which it is expoſed, he next proceeds to examine the ſtate of the air, to which ſome blood has been expoſed; and he found, agreeable to his ſuppoſition, that after having expoſed ſome craſſamentum to a quantity of dephlogiſticated air for ſeveral hours, that elaſtic fluid became thereby very much phlogiſticated, as it appeared by the taſte of nitrous air †. Uſing at different times black and florid red blood, he alſo obſerved, that the dephlogiſticated air was depraved conſiderably more by the former, than by the latter. Thoſe experiments prove clearly, that black blood imparts phlogiſton to the air; but the reverſe of this propoſition, viz. that blood has a power of abſorbing phlogiſton from thoſe elaſtic fluids which abound with it, Dr. PRIESTLEY proved by expoſing blood, of a very beautiful florid colour, to nitrous, inflammable, and phlogiſticated air; the reſults of which experiments were, that thoſe ſorts of elaſtic fluids, after having been thus treated, were found to have ſenſibly loſt part of their phlogiſton; for the nitrous air had in part loſt its power

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* PRIESTLEY'S Exper. and Obſerv. vol. iii. ſect. 5.

† The pieces of blood in theſe experiments were changed very often, in order that they might not become putrid; for it is well known, that the putrefaction of every ſubſtance injures good air.

of diminiſhing common air; the inflammable air was rendered wholeſome in ſome degree, ſo as to ſuffer a conſiderable diminution when mixed with nitrous air; and the phlogiſticated air became alſo diminiſhable by nitrous air, though not much. "But," ſays he, "it ſhould be conſidered, that the proper "function of the blood is not to receive phlogiſton from *air*, "(not meeting with any phlogiſticated air in the courſe of "its circulation) but to communicate phlogiſton to air; and "therefore, there is by no means the ſame reaſon to expect "that air will be mended by red blood, as that it will be "injured by black blood*."

After the recital of thoſe experiments, the judicious Doctor, in his paper *on reſpiration, and the uſe of the blood*, takes notice of an objection, which might, with great reaſon, be oppoſed to his doctrine, viz. that the blood never comes into actual contact with the air introduced into the lungs; for a thin membrane, which Dr. HALES ſuppoſes to be about one thouſandth part of an inch thick, ſeparates it from that elaſtic fluid. The following are the Doctor's words. "In order to "aſcertain the effect of theſe circumſtances, I took a large "quantity of black blood, put it into a bladder, moiſtened "with a little ſerum, and tying it very cloſe, hung it in a "free expoſure to the air, though in a quieſcent ſtate; and "the next day I found, upon examination, that all the lower "ſurface of the blood, which had been ſeparated from the "common air by the intervention of the bladder (which is

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* Exper. and Obſer. vol. iii. ſect. 5.

" an animal membrane, ſimilar to that which conſtitutes the " veſicles of the lungs, and is at leaſt as thick) and likewiſe " a little ſerum, had acquired a coating of a florid red colour, " and as thick, I believe, as it would have acquired, if it had " been immediately expoſed to the open air; ſo that this " membrane had been no impediment to the action of the air " upon the blood. In this caſe it is evident to obſerve, that " the change of colour could not be owing to *evaporation*, as " Mr. CIGNA conjectures. This experiment I repeated, " without previouſly moiſtening the bladder, and with the " very ſame reſult.

" I obſerved alſo, that when I cut out a piece of the craſ" ſamentum, and left the remainder in the veſſel with the " ſerum, not only that part of the ſurface which was expoſed " to the air, but that which was ſurrounded with ſerum, and " even covered with it to the depth of ſeveral inches, ac" quired the florid colour; ſo that this deep covering of " ſerum, which muſt have effectually prevented all evapora" tion, was no more an impediment to the mutual action of " the blood and the air, than the bladder had been. The " ſerum of the blood, therefore, appears to be as wonderfully " adapted to anſwer its purpoſe, of a vehicle for the red glo" bules, as the red globules themſelves; for the ſlighteſt " covering of water, or *ſaliva*, effectually prevents the blood " from acquiring its florid colour; and Mr. CIGNA found " that this was the caſe when it was covered with oil.

" That it is really the *air*, acting through the ſerum, and

" not the ſerum itſelf, that gives the florid colour to the " blood, is clearly aſcertained by the following experiment. " —I took two equal portions of black blood, and put them " into equal cups, containing equal quantities of ſerum, " which covered them to the depth of half an inch. One of " theſe cups ſtanding in the open air, and the other being " placed under an exhauſted receiver, the former preſently " acquired a florid colour, while the other continued twelve " hours as black as at firſt. Being taken out of the receiver, " it ſtood all night in the open air without becoming red, " and continued black ever after, even when the ſerum was " poured off.

" I alſo more compleatly ſatisfied myſelf of the influence " of the air upon the blood, through a body of ſerum, by the " reverſe of this experiment; for I found that red blood be" came black through the depth of two inches of ſerum, " when the veſſel containing it was expoſed to phlogiſticated " air; ſo that the red globules of the blood both receive, and " part with phlogiſton by means of the air, notwithſtanding " the interpoſition of a large body of the fluid in which they " naturally float."

Thus the office of the air in the lungs was ſatisfactorily demonſtrated, by clear and well-conducted experiments.—It is very remarkable, that about the ſame time that thoſe experiments were publiſhed in England, Mr. SCHEELE, (an able German Apothecary, and member of the Royal Academy at Stockholm), to whom the firſt publications of Dr. PRIESTLEY's

Experiments and Obſervations were well known, ſhould publiſh an explanation of the office of the air in reſpiration, which is quite the reverſe of the above-mentioned doctrine of Dr. PRIESTLEY.—The Doctor ſhews that the air acquires phlogiſton from the blood through the lungs; and Mr. SCHEELE ſays, that the blood acquires phlogiſton from the air. "Phlogiſton," *ſays he* *, "which communicates, for the greater part, to thoſe ſubſtances with which it is united, fluidity, mobility, and elaſticity; muſt have the ſame effect on blood. The globules of the blood muſt attract it from the air, through the ſmall pores of the pulmonary veſicles; by this union they are ſeparated, and conſequently made more fluid, and appear then very red. They ought, however, to depoſit this attracted phlogiſton during circulation; and conſequently be enabled to imbibe again from the air, the phlogiſton in the place where they come the neareſt in contact with it, i.e. in the lungs. What may have become of this phlogiſton, I leave to others to determine."

This perſon, knowing that blood newly taken, and expoſed to the open air, acquires a florid red colour on its ſurface, examined the alteration that this change of colour might produce in the air, in the following manner:—He put ſome blood, newly taken, into a matraſs, which he tied up with a bladder, and agitated it frequently. Eight hours after, examining the air of this matraſs, he found that it did not contain any fixed air, neither had it been diminiſhed; but it extinguiſhed the flame of a candle immediately; in ſhort, it was in that ſtate which we might call *phlogiſticated*; though Mr. SCHEELE does not think that the air in that ſtate has acquired any ſuperfluous quantity of phlogiſton.—As for the theory of this author, relating to the uſe of the air in reſpiration, vegetation, &c. it ſhall be taken proper notice of in another place of this work; but I ſhall, for the preſent, only mention the principal experiment, which was the cauſe of the above-mentioned miſtaken notion. Mr. SCHEELE having adapted a tube to the neck of a bladder, filled it with inflammable air extracted from oil of vitriol and ſteel filings; then applying the tube of the ſaid bladder to his mouth, and ſtopping, at the ſame time, both his noſtrils with one hand, he inhaled that elaſtic fluid twenty times, which was as much as he could; then, ſays he, "having again recovered in ſome meaſure, I again expelled "the air from the lungs as much as poſſible, and then drew "in again this inflammable air. After ten inhalations, I "found myſelf obliged to leave off, and found that it was "no more inflammable, nor could it unite with lime-water; "in a word, it was foul air."

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* Exper. on Air and Fire, tranſlated by Dr. FORSTER, p. 150.

By the words, "I again expelled the air from the lungs," it ſeems as if the experiment had all the appearance of accuracy; for the quantity of common air, which remains in the lungs after a natural expiration, and which in Mr. SCHEELE's experiment muſt be evidently mixed with the inflammable air of the bladder, might be conſidered to be very ſmall; yet the reader may reſt aſſured that the principal reſults of this experiment of Mr. SCHEELE's, are quite contrary to the common obſervations of all the other moſt able philoſophers, who have diſtinguiſhed themſelves in this branch of philoſophy; eſpecially of the learned Mr. FONTANA, who examined this particular ſubject with the moſt ſcrupulous and unwearied attention. Mr. SCHEELE aſſerts, that after the inflammable air had been breathed as long as it could, it loſt its inflammable property; but Mr. FONTANA, beſides ſeveral other perſons, has found, that the inflammable air, extracted from the very ſame ſubſtances uſed by Mr. SCHEELE, as well as from others, after having breathed by birds and quadrupeds till they died, after being breathed by himſelf, even when mixed with common air, was always inflammable; he having fired it even on the act of blowing it out of his mouth. In regard to the inflammable air being capable of being breathed without danger, Mr. FONTANA found the caſe to be quite the contrary. Indeed, that animals introduced into inflammable air died preſently, had been obſerved before, by Mr. CAVENDISH, Dr. PRIESTLEY, and others; but Mr. FONTANA, by particular and numerous experiments, the account of which will be given in the chapter that treats of inflammable air, ſhews that inflammable air, whether it be breathed through the noſtrils and mouth, or through the mouth only; whether it be breathed by birds, quadrupeds, or men; whether the whole body of the animal is introduced into the inflammable air, or the mouth only; and whether it be breathed out of bladders or out of glaſs receivers; is always noxious*. In ſo much it may be breathed for a few times, as the air of the lungs, which remains in them even after an expiration, mixes with it, and which air being ſpecifically heavier than inflammable air, muſt generally remain at the bottom, viz. in contact with the lungs; from whence it follows, as it has been proved by experiments, that the inflammable air proves more noxious, when the bladder or other veſſel containing it, that is applied to the mouth, is larger, than when ſmaller; for then the quantity of pulmonary air that is mixed with the inflammable air is proportionately ſmaller. We muſt therefore conclude that Mr. SCHEELE's hypotheſis is erroneous, and that the uſe of the air in reſpiration is, as Dr. PRIESTLEY has ſhewn, principally to carry off the phlogiſton from the blood.

It is neceſſary, in this place, to ſpeak of the ſeparation of heat from the air in reſpiration; which affords the explanation of a remarkable phenomenon in the animal body, to wit, the *animal heat*; and which has been ably ſhewn by Dr. CRAWFORD's ingenious experiments, publiſhed in his work entitled *Experiments and Obſervations on Animal Heat.* This author, whoſe ſyſtem has been mentioned towards the beginning of this work, obſerves, that,

" 1. Thoſe animals which are furniſhed with lungs, and " which continually inſpire the freſh air in great quantities,

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* Phil. Tranſ. vol. lxix.

"have the power of keeping themſelves at a temperature "conſiderably higher than the ſurrounding atmoſphere. "But animals that are not furniſhed with reſpiratory organs, "are very nearly of the ſame temperature with the medium "in which they live.

"2. Among the hot animals, thoſe are the warmeſt, which "have the largeſt reſpiratory organs, and which, conſequently, "breathe the greateſt quantity of air in proportion to their "bulk. Thus, the reſpiratory organs of birds, compared with "their ſize, are more extenſive than thoſe of any other "animal; and birds have the greateſt degree of animal heat.

"3. In the ſame animal, the degree of heat is, in ſome "meaſure, proportionable to the quantity of air inſpired in a "given time. Thus, we find that animal heat is increaſed "by exerciſe, and by whatever accelerates reſpiration.

After theſe obſervations, Dr. Crawford next proceeds to demonſtrate experimentally the following propoſitions, viz. I. That common air contains a greater quantity of elementary heat, than the air that is expired from the lungs; and that the quantity of this elementary heat contained in any ſort of air, that is fit for reſpiration, is nearly proportionable to its purity. II. That the blood which paſſes from the lungs to the heart, by the pulmonary vein, contains more elementary heat, than that which paſſes from the heart to the lungs, by the pulmonary artery. III. That the capacities of containing the elementary heat in bodies, are diminiſhed by the addition of phlogiſton, and increaſed by the ſeparation of this principle *.

Then the explanation of animal heat, which he deduces from thoſe propoſitions, is as follows:—The atmoſpherical, or, in general, the reſpirable air, which is introduced into the lungs, acquires a quantity of phlogiſton from the blood.—By being impregnated with phlogiſton, its capacity of holding elementary heat is leſſened, according to the third propoſition; hence it muſt depoſit part of that heat upon the blood, which thus acquiring an additional quantity of heat, diſperſes it through the body, and thus keeps up that warmth which breathing animals have above the uſual temperature of the atmoſphere.

It will perhaps be difficult for ſome perſons to reconcile this theory with the uſual popular obſervation, that the air which is expired from the lungs is ſenſibly hotter than that which is inſpired; whereas, according to the above-mentioned theory, the air expired contains leſs elementary heat, than it did before its entering the lungs; but it muſt be obſerved, that the heat of the air juſt expelled from the lungs is a ſenſible heat, which has nothing to do with the air's capacity of holding that element. For example, ſuppoſe that the common atmoſpheric air contains 20 parts of elementary heat, and that the ſame air, after being breathed once, can contain not more than 10 of thoſe parts. Now thoſe two ſorts of

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* For the experiments, which prove theſe propoſitions, the reader is referred to the above-mentioned work *on animal heat*.

elaſtic fluid, viz. common atmoſpheric air, and the ſame air after being breathed, when put in the ſame temperature, acquire the ſame degree of ſenſible heat, viz. they will raiſe the thermometer preciſely to the ſame degree, notwithſtanding that the former contains, according to the ſuppoſition, twice as much elementary heat as the latter; for the quantity of elementary heat, that a body contains, does not become ſenſible, unleſs the capacity of that body for holding ſo much heat is leſſened. The air then which is expired from the lungs has a quantity of ſenſible heat, which it has acquired from its contact with the warm lungs, and which it loſes as ſoon as it comes into contact with colder bodies; but its quantity of elementary heat remains leſs than it was before its being uſed for reſpiration; becauſe, according to Dr. CRAWFORD's theory, its capacity of holding that element is leſſened by its being impregnated with phlogiſton.

The novelty of this theory, and its being not eaſily reconcileable with the ſenſible and vulgar appearances, renders a more explicit and fuller explanation neceſſary, in order to render it familiar to perſons not much verſed with theſe diſquiſitions, and even to philoſophical minds; but the ſubject being rather foreign to the principal object of this work, I muſt forbear expatiating upon it.

Having examined particularly the principal properties of air in reſpiration, it is now neceſſary to collect, under one point of view, all the particulars relating to that moſt intereſting function of the animal body, in order that the reader may form a juſt and comprehenſive idea of the ſame; eſpecially reſpecting the human body.

A man generally performs one inſpiration for every ſeven or eight pulſations of the heart; and, as the mean number of pulſations, between thoſe that are very quick, and thoſe that are remarkably ſlow, may be taken to be 90 per minute, we may ſuppoſe that at a mean, 14 inſpirations and 14 expirations are performed in each minute.

A perſon of an ordinary ſize, and in good health, may be reaſonably ſuppoſed to inſpire 30 cubic inches of air at a time. In the expiration the air is not intirely changed, but ſome of it remains in the lungs, wind-pipe, and mouth; which is generally more in quantity than that uſually taken in and expelled in the act of ordinary reſpiration; ſo that in a very violent expiration, following a natural inſpiration, the air expelled from the lungs may amount to 60 cubic inches, viz. the double of that quantity which is expelled in a natural expiration. And even in caſe of this violent expiration, ſome air ſtill remains in the mouth, *aſpera arteria*, or wind-pipe, and its branches. Reſpiration is quickened by various cauſes, as by the acceleration of pulſation, by agitation, diſeaſes of the lungs, and impurity or rarity of the air. An animal confined in a limited quantity of air, quickens its inſpirations in proportion as the air becomes leſs fit for reſpiration, and alſo takes in and expels more air at a time, than when the air is purer. This ſame effect is obſervable when an animal is put under the receiver of an air-pump, out of which the air is partly exhauſted. The air, when introduced into the lungs, becomes impregnated with phlogiſton, and, at the ſame time, depoſits ſome of its elementary heat upon the blood; its capacity of holding that element being leſſened by the acquiſition of phlogiſton: and, on the contrary, the blood having depoſited ſome phlogiſton upon the air through the ſerum, and pores of the pulmonary veſicles, acquires heat from it; hence the blood which paſſes from the lungs to the heart contains more elementary heat and leſs phlogiſton than that which paſſes from the heart to the lungs. The air which has ſerved for one inſpiration is not thereby compleatly phlogiſticated, but is ſtill uſeful for reſpiration, though it is leſs fit for it than new air; and according as it is more uſed, it becomes more and more infected, until it is rendered quite unfit for reſpiration. Mr. FONTANA having introduced 350 cubic inches of common air into a bladder, and, applying the neck of it to his mouth, after having made as ſtrong an expiration as he could, endeavoured to breathe it as long as it was poſſible; but after having breathed it forty times, his ſtrength began to fail, ſo that he was obliged to deſiſt*. Mr. SCHEELE ſays, that he has breathed the air contained in a bladder 24 times, which was as much as he poſſibly could†; but Mr. SCHEELE does not mention the capacity of the bladder uſed, ſo that nothing preciſe can be deduced from his experiment. This property of contaminating air is different with different individuals of the human ſpecies, and alſo with other animals; there being ſome people who phlogiſticate the air much ſooner than others, eſpecially when affected by particular diſeaſes; and ſome animals are ſaid to have the property of infecting common air ſo ſoon, and in ſo great a degree, that their breath is quite mortiferous to other animals that happen to be involved in it. Dr. PRIESTLEY has obſerved, "that "young mice will always live much longer than old ones, or "than thoſe which are full grown, when they are confined "in the ſame quantity of air; having ſometimes known a "young mouſe to live ſix hours in the ſame circumſtances in "which an old mouſe has not lived one*." This obſervation ſeems to ſhew that young mice do not phlogiſticate the air ſo ſoon as old ones do; and, conſidering the various cauſes upon which this may depend, it ſeems probable that this law is true with the generality of animals, and eſpecially with mankind, viz. that the old individuals contaminate the air ſooner than the young ones. Upon this natural ſuppoſition, it may perhaps be conſidered diſadvantageous for young people to ſleep with old perſons; for the latter contaminating the air much quicker, may render the reſpiration of the young people unhealthy and difficult, eſpecially becauſe the air about a bed is very little agitated. It does not follow from thence, that the air breathed by young people is ſalutary for the old, as ſome ignorant perſons believe. It is probably leſs impure than if it had been breathed by old perſons; but it is always leſs fit for reſpiration than the common air, which has not been at all breathed. "It is a very erroneous "opinion," ſays Dr. INGEN-HOUSZ, "and even tending to "do material miſchief, that the air of a room, in which a "great number of young people have been ſhut up, as in "ſchools, is become very wholeſome for old people to "breathe in. I have ſeen ſchool-maſters ſo ſtrongly prejudiced with this notion, that they even would not allow the "windows of the ſchool to be opened, for fear that the "young air, as they called it, of the ſchool-boys ſhould "eſcape; thinking that breathing this infectious and truly "noxious evaporation would prolong their own life *."

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* Phil. Tranſ. vol. lxix.

† Exp. on Air and Fire, p. 147.

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* PRIESTLEY's Exper. and Obſerv. vol. i. p. 72.

The air thus rendered compleatly noxious by animal reſpiration, is deleterious to other animals, extinguiſhes flame, is very little diminiſhable by nitrous air, and precipitates the lime in lime-water, or cryſtallizes with oil of tartar †; which ſhews that it contains a quantity of fixed air: which may be alſo ſeparated from it by agitation in water; for the fixed air being miſcible with water, is abſorbed by it, and then the depraved air, &c. is diminiſhed in bulk. The quantity of fixed air, which Mr. SCHEELE aſſerts to have ſeparated, by means of

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* Experiments on Vegetables, p. 134.

† In order to let fixed air, whether by itſelf or when mixed with other elaſtic fluids, cryſtallize with oil of tartar, the inſide ſurface of a ſmall glaſs receiver muſt be ſmeared with oil of tartar, then the receiver being filled with and inverted in quickſilver, the elaſtic fluid is introduced into it, which will cryſtallize with the alkaline liquor upon the inſide ſurface of the receiver.

lime-water, from ſome air which he had breathed as long as he could, was about one thirtieth part of the whole quantity*. The air which Mr. FONTANA had breathed forty times, as above-mentioned, being examined by himſelf, was found to extinguiſh a light ſeveral times ſucceſſively†. It formed various cryſtals with oil of tartar, but after a very conſiderable time; ſome of which cryſtals had the ſhape of needles, others were like flowers. By the taſte of nitrous air, it gave II, I. 2,70. and II, II. 3,70. (his marks being expreſſed according to our method of notation) as was mentioned in the VI. Chap. of the preceding Part ‡. A ſmall bird, being introduced into a receiver containing ten cubic inches of that air, made ſeveral contortions with its body, as ſoon as it began to breathe it, ſhewing to ſuffer a great deal, and it died in ten minutes time; whereas another little bird, introduced into a like quantity of common air, lived in it fifty-two minutes, nor did it ſhew any ſign of uneaſineſs before it had been in five minutes §.

Air is diminiſhed by animals breathing in it, as Mr. BOYLE firſt obſerved. This experiment cannot be made by applying a bladder full of air to the mouth, and breathing in it; for then the diminution cannot be obſerved with preciſion: but the whole body of an animal muſt be introduced into a ſufficiently large receiver, and either it ſhould be prevented by proper management, or proper allowance ſhould be made for any error that might ariſe from the heat of the animal's body, from its putrifying in the receiver after death, or from other like circumſtances. This diminution Dr. HALES obſerved to be about one thirteenth of the whole quantity. Mr. SCHEELE aſſerts, that after keeping a rat in a quantity of air till it died, the air was thereby diminiſhed very little; but his experiment was conducted in a very equivocal manner, ſo as to render the reſult very doubtful. Dr. PRIESTLEY has found this diminution to amount to one ſixth, or one fifth. Indeed, air is diminiſhed not only by reſpiration, but, in general, by every phlogiſtic proceſs, as combuſtion, putrefaction, &c. excepting, however, when ſome elaſtic fluid is generated by the ſubſtances expoſed to that air; which caſes, properly ſpeaking, are not exceptions againſt the air being diminiſhed; but, mixing the diminiſhed air with the produced elaſtic fluid, prevents our obſerving the actual diminution of the atmoſpheric fluid.

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* Exper. on Air and Fire, p. 147, and 148.

† A lighted wax taper is let down into a receiver containing the elaſtic fluid, and when extinguiſhed in it, the mouth of the receiver is ſtopped, and the wax taper is lighted again, and is let down into the ſame receiver a ſecond time, and ſo on.

‡ Viz. two meaſures of the breathed air and one of nitrous air were reduced to two meaſures and 70 100ths; to which another meaſure of nitrous air being added, the whole was reduced to three meaſures and 70 100ths.

§ Phil. Tranſ. vol. lxix. p. 343.

The animals which, by being introduced into air depraved by the reſpiration of other animals, are deprived of life, ſeem to be affected by ſomething ſtimulating in that fluid; for they generally die in convulſions, and are often affected ſo quickly, that they are irrecoverable, even if withdrawn after a ſingle inſpiration. The fixed air, exiſting in air infected by animal reſpiration, ſeems chiefly to produce this effect of ſuffocating, &c. A ſmall animal, as a bird, introduced into a tall receiver full of air, will live longer if, by ſome means, it is placed towards the top of the receiver, than if at the lower part of it; the reaſon of which phenomenon ſeems to be, the fixed air generated by the animal's reſpiration, which, on account of its being heavier than common air, falls to the lower part of the receiver. It is remarkable, that animals may be habituated to live in ſuch foul air much longer than other animals, which are not uſed to it; ſo that if a mouſe, as Dr. PRIESTLEY ſays, can ſtand the firſt ſhock of the ſtimulus, occaſioned by this elaſtic fluid, or has been habituated to it by degrees, it will live a conſiderable time in air in which other mice will die inſtantaneouſly.

Inſects have the remarkable property of living very well in air that is tainted, not only by reſpiration, but even by putrefaction of animal or vegetable ſubſtances. "Inſects of various kinds," ſays Dr. PRIESTLEY, "live perfectly well in air "tainted with animal or vegetable putrefaction, when a "ſingle inſpiration of it would have inſtantly killed any other "animal. I have frequently tried the experiment with flies "and butterflies. The *aphides*, alſo, will thrive as well upon "plants growing in this kind of air, as in the open air. I "have even been frequently obliged to take plants out of the "putrid air, in which they were growing, on purpoſe to

" bruſh away the ſwarms of thoſe inſects which infected " them; and yet ſo effectually did ſome of them conceal " themſelves, and ſo faſt did they multiply, in theſe circum" ſtances, that I could ſeldom keep the plants quite clear of " them †."

Independent of Dr. PRIESTLEY's obſervation, one might be eaſily induced to ſuppoſe the ſame thing, by remarking that a vaſt number of inſects is generally found near putrid marſhes, and in thoſe places in which the air is manifeſtly impregnated with offenſive and putrid effluvia.

Mr. SCHEELE having confined ſome flies, and alſo ſome bees, in ſmall receivers full of air, found that after ſome days they always died, notwithſtanding that proper food for them was alſo laid in thoſe receivers ‡. This obſervation ſeems, at firſt ſight, to be contradictory to Dr. PRIESTLEY's experiments; but it muſt be conſidered that the Doctor confined the inſects in putrid air, whereas Mr. SCHEELE confined them in common air, which was gradually infected by their own reſpiration, &c. Probably thoſe two kinds of air produce different effects upon inſects. The experiment may be eaſily tried. Nevertheleſs, Mr. SCHEELE's method of performing experiments in general is not very accurate; and as he ſpeaks of a great diminution of air to have taken place in his above-mentioned experiments with inſects, which does not ſeem to be very probable, nor has it been obſerved in ſome like trials, which I lately made; I am apt to think, that Mr. SCHEELE's experiments muſt have been, in ſome manner or other, miſtaken.

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† Exper. and Obſerv. vol. i. p. 85.

‡ "EXPERIMENT III.

" I ſhut up ſome flies in a phial, into which I had laid a paper whereon I put " ſome honey: ſome days after they all were dead; but they had not abſorbed " any air. The milk of lime *(he means lime-water)* diminiſhed its bulk of about " one fourth part, and the reſt extinguiſhed a candle.

" Then I took a bottle of twenty ounces meaſure, and near its bottom I bored " a hole in it with the corner of a broken file; into this bottle I put a ſmall " piece of quick-lime, and ſhut its mouth with a cork, through which I had " paſſed a tube; round the cork I laid a ring of pitch, and having put a bee " with ſome honey on a paper into a common open glaſs, I ſet it inverted on the " pitch (into which I gently preſſed the glaſs, in order to exclude all communi" cation of external air); then the bottle was placed in a diſh; this I filled ſo far " with water as to cover half of the bottle; finding the water lifted the bottle " off from the bottom of the diſh, I laid a ſmall weight on the top of the inverted " glaſs.

Beſides the principal uſe of the air in reſpiration, viz. the ſeparating the ſuperfluous phlogiſton from the blood; it ſerves alſo to expel from the animal body putrid effluvia, as is ſhewn by the offenſive ſmell of ſome perſons that have a bad habit of body; and, in general, it certainly expels ſome moiſture from the lungs, as it is ſhewn by the vapour of

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" glaſs. The water mounted every day into the bottle by the hole. I took " care now and then to ſhake the bottle, in order to burſt the ſkin formed on " the ſurface of the water. At the end of ſeven days the water was riſen to E " *(i. e. to about one fifth of the inverted glaſs)*, and the bee was dead: ſometimes I " put two bees at a time into the glaſs, when the ſame quantity of air has been " changed into aërial acid *(i. e. fixed air)* in half the time. Caterpillars and " butterflies cauſe the ſame effect." SCHEELE's Exper. on Air and Fire. p. 148.

the breath appearing in a coldiſh temperature †. In that caſe, the air which is in the lungs, being hot, diſſolves, and combines with a greater quantity of watery particles than the open air; but when expelled from the lungs, it becomes ſuddenly cold by the contact with the open air; hence ſome of the particles of water, being precipitated from it, are collected together ſo as to form that viſible vapour; which ſoon diſappears, becauſe it mixes with the common ſtock of air.

Nature has alſo employed reſpiration to various mechanical purpoſes, as for the voice, the cough, &c.; for which ſee the anatomical and phyſiological writers ‡.

Thus we have examined the intereſting office of air in reſpiration, and the alteration it undergoes by being ſubſervient to that natural proceſs. We ſhall next examine it in reſpect to combuſtion. Air, in a natural ſtate, promotes, and is abſolutely neceſſary for the combuſtion of inflammable bodies. Thus a candle is extinguiſhed in vacuo, but burns in the open air. A quantity of air cannot aſſiſt the combuſtion for more than a limited time; about a gallon of common air being ſufficient to ſupport the combuſtion of an ordinary tallow candle for one minute only; after which the candle is extinguiſhed, and that quantity of air becomes thereby incapable to aſſiſt combuſtion any farther. Thus if a candle is introduced into a receiver full of air, that has been contaminated by the burning of another candle, or of charcoal, or of any other combuſtible matter, it is extinguiſhed immediately*.

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† The breath, or the vapour of the air coming out of the lungs, is only to be ſeen in a temperature colder than the 60th, or, at moſt, the 61ſt degree of FARENHEIT's thermometer.

‡ Etmuller Diſſert. 2. chap. 10.——Galen *de uſu partium*, L. 5. c. 15. Haller, vol. iii. &c.

Air is diminiſhed by the proceſs of combuſtion; ſo that if a piece of charcoal b burned, by throwing the focus of a lens on it, when contained in a glaſs receiver inverted in water; after that the apparatus is grown cold, the water will be ſeen to mount a ſhort way up the receiver. This diminution is limited, though its quantity depends upon ſeveral circumſtances. Dr. HALES has obſerved, that in equal receivers the air ſuffered a greater diminution by burning large candles than ſmall ones; and alſo, that when equal candles were uſed, the diminution was comparatively greater in ſmall than in large receivers. The cauſe of this phenomenon is, probably, becauſe the air contained in a receiver cannot all come into contact with the flame of the candle; hence, as ſoon as the air, which is neareſt to the flame, becomes contaminated, the candle is extinguiſhed. Thus the author of a conciſe treatiſe *on the various kinds of permanently elaſtic fluids*, has diminiſhed the air of an inverted receiver of one ſixth part, by moving the candle, whilſt it burned, through the different parts of the receiver, ſo as to bring the flame into contact with more of the confined air, than if the candle had remained ſtill in one ſituation till it became extinct; whereas Dr. Mayow obſerved, that by the burning of a candle the air was diminiſhed of one thirtieth only; Dr. Hales found it to be diminiſhed of one twenty-ſixth part; and Dr. Priestley found it to be diminiſhed of one fifteenth, or ſixteenth.—Mr. Cavendish obſerved, that air ſuffered a diminution of one tenth of the whole quantity, by paſſing through an iron tube filled with red-hot powder of charcoal. A candle, or any other combuſtible body, will ceaſe to burn by itſelf, and conſequently to contaminate a quantity of confined air much ſooner than when it is, in ſome manner, forced to burn by the external application, of heat. "The focus of a burning "mirror," ſays Dr. Priestley, "thrown for a ſufficient "time either upon brimſtone or wood, after it has ceaſed to "burn of its own accord, and has become *charcoal*, will have "a much greater effect of the ſame kind, diminiſhing the air "to its utmoſt extent, and making it thoroughly noxious *." The combuſtion of the phoſphorus of urine diminiſhes air in a great degree. Mr. Lavoisier has obſerved, that by the combuſtion of phoſphorus, air may be diminiſhed of about one fifth, or one ſixth. This accurate philoſopher has alſo obſerved, that the acid of phoſphorus, thus formed, acquires the weight loſt by the diminiſhed air; finding that about three inches of air were abſorbed by every one grain of phoſphorus, when the experiment was tried with a receiver inverted in water, upon the ſurface of which a ſmall quantity of oil had been introduced; but when the receiver was inverted in quickſilver, the abſorbtion was conſtantly between $2\frac{1}{4}$ and $2\frac{3}{4}$ inches for each grain[*]. I have often repeated the experiment of burning phoſphorus in a glaſs tube inverted in water, by applying the cloſed part of the tube, wherein the phoſphorus was contained, to a pretty ſtrong fire, and have always obſerved, that the utmoſt diminution of the incloſed air, effected by this means, was full one fifth.

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* Dr. DESAGULIERS obſerved, that air which had paſſed through burning coals extinguiſhed flame immediately.

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* Exper. and Obſerv. vol. i. p. 47.

Dr. HALES remarked, that after the extinction of candles in a receiver, the air continued to diminiſh for ſeveral days after.—This may be owing to the gradual abſorbtion of part of it by the water; it having been remarked by Dr. PRIESTLEY, "that this diminution of air by burning is not "always immediately apparent, till the air has paſſed ſeveral "times through water; and that when the experiment was "made with veſſels ſtanding in quickſilver inſtead of water, "the diminution was generally inconſiderable till the air had "paſſed through water[†]."

In theſe experiments of burning combuſtible bodies in a quantity of air, and meaſuring the diminution, we ſhould always remark two cauſes of miſtake, viz. the abſorbtion of air by the coaly reſiduum of the burned matter, which ſometimes is very conſiderable, or by the fluid in which the receiver is inverted; and the production of elaſtic fluid from the burning ſubſtances: thus gunpowder generates a great quantity of elaſtic fluid, when inflamed, &c.

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[*] LAVOISIER's Eſſays, phyſical and chemical, p. 378, and following.

[†] Exper. and Obſerv. vol. i. p. 46.

Air, which has been uſed for combuſtion, precipitates the lime in lime-water; which ſhews, that by the act of combuſtion ſome fixed air is generated, or at leaſt, it muſt be ſome other fluid capable of precipitating the lime like fixed air.

Thus we have enumerated the phenomena of combuſtion in air; we muſt next endeavour to explain their cauſes; examining the moſt probable hypotheſes hitherto offered.

That combuſtible bodies, by the act of burning, part with their phlogiſton, is evident, ſince the reſiduum which they leave behind after combuſtion retains very little of that principle. The air in which bodies have been burning, is unfit for the combuſtion of other bodies, exactly as the air that has ſerved for reſpiration, and which has been ſhewn to be a phlogiſtic proceſs; hence it follows, very naturally, that the phlogiſton ſeparated from thoſe bodies is communicated to the air; which is therefore ſaid to be *phlogiſticated.* It has been a great difficulty, with many philoſophers, to account for the heat produced in the combuſtion of bodies; ſome having attributed it to vibrations, excited by the eſcape of the inflammable principle, or by the parts of the burning body; others conſidering that heat, or the elementary fire, of which, however, they had no clear notion, being diſperſed throughout the univerſe, was put in action by the burning bodies; others again, confounding heat and fire with light, formed an unintelligible hypotheſis: in ſhort, various have been the opinions concerning this great natural phenomenon; but none has ſo much the appearance of truth, and ſeems ſo ſatisfactory to the mind, as Dr. CRAWFORD's explanation; which I ſhall here ſubjoin in his own words.

" From the above experiments we learn, that atmoſpheri-
" cal air contains much abſolute heat; that when it is con-
" verted into fixed and phlogiſticated air, the greater part of
" this heat is detached; and that the capacities of bodies for
" containing heat are diminiſhed by the addition of phlo-
" giſton, and increaſed by the ſeparation of it. From hence
" we infer, that the heat which is produced by combuſtion,
" is derived from the air, and not from the inflammable
" body.

" For inflammable bodies abound with phlogiſton, and
" contain little abſolute heat; atmoſpherical air, on the con-
" trary, abounds with abſolute heat, and contains little
" phlogiſton. In the proceſs of inflammation, the phlogiſton
" is ſeparated from the inflammable body, and combined with
" the air; the air is converted into fixed and phlogiſticated
" air, and at the ſame time gives off a very great proportion
" of its abſolute heat, which, when extricated ſuddenly,
" burſts forth into flame, and produces an intenſe degree of
" ſenſible heat."

And a few lines after he ſays,

" It is manifeſt, on the contrary, that no part of the heat

" can be derived from the combuſtible body; for the combuſtible body, during the inflammation, being deprived of its " phlogiſton, undergoes a change ſimilar to that which is " produced in the blood, by the proceſs of reſpiration; in " conſequence of which, its capacity for containing heat " is increaſed. It, therefore, will not give off any part of its " abſolute heat, but, like the blood in its paſſage through the " lungs, it will abſorb heat*."

I ſhall here add another explanation of combuſtion, which does not ſeem to be very ſatisfactory; yet I think it neceſſary to mention it in this place, ſince its author, Mr. SCHEELE, is a late writer of great reputation in the philoſophical world.

The reader muſt firſt be informed, that this author ſuppoſes that the common atmoſpheric air is compounded of two elaſtic fluids, namely, one that has no attraction to phlogiſton, and another which is dephlogiſticated air, by him called *empyreal air*, which has a ſtrong attraction to phlogiſton, and which makes between a third and a fourth part of the whole bulk of air. His theory is expreſſed in the following eight propoſitions.

" 1. To every combuſtible body a certain quantity of heat " muſt be communicated, in order to ſet it in the fiery " commotion.

" 2. Then it is enabled to part with its phlogiſton, provided there be a ſubſtance preſent, which has a ſtronger

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* Exper. and Obſer. on animal heat, p. 76.

" attraction to the inflammable than that with which it was " before in union.

" 3. If the heating is done in the open air, the empyreal " air has the ſtronger attraction.

" 4. Immediately after, the inflammable principle muſt " come out and unite with the empyreal air, and thus be ſet " at liberty.

" 5. From this union heat is compounded; which adheres " to foul air, expands it, and riſes according to hydroſtatical " principles.

" 6. Scarcely is this heat generated, when the combuſtible " body is ſtill more expanded by it than in the beginning, " and its phlogiſton is more laid open.

" 7. Empyreal air comes in contact with more phlogiſton, " and, according to its nature, forms an union with a greater " quantity of it, which cauſes radiant heat.

" 8. And at that very moment the integrant parts of the " combuſtible body are ſo much diſunited by the ſtill increaſing heat, that the empyreal air continuing to pour " upon it in ſtreams, attracts the phlogiſton in ſtill greater " quantities; and hence (that wonderful phenomenon) the " moſt elaſtic ſubſtance, *Light*, is compoſed; which, according to the quantity of combuſtible matter, has various " colours *.

The reader may eaſily diſcern in this theory ſome ideas that come very near to that of Dr. CRAWFORD; though upon the whole it is quite a different thing.

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* Scheele's Exper. on Air and Fire, p. 111.

The elaſtic fluid, which being formed in the act of combuſtion, is abſorbed by water, and precipitates the lime in lime-water, ſeems to be fixed air, or calcareous gas; for they agree in all their hitherto-obſerved properties, viz. they are ſpecifically heavier than common air, they precipitate the lime in lime-water, they are miſcible with water, and they give manifeſt ſigns of acidity; for the water that has imbibed a conſiderable quantity of it, turns the blue juice of radiſhes into red. But the difficulty conſiſts in aſcertaining the origin of this gas, viz. whether it proceeds from the air, or from the combuſtible body, or is formed in the act of combuſtion by the mixture of ſome of thoſe principles, which are in that proceſs ſeparated from both the air and combuſtible body. Dr. PRIESTLEY ſeems to have aſcertained, that this gas, or fixed air, cannot be produced by merely heating the inflammable body, without actual combuſtion; for when he directed the focus of a burning-glaſs upon pieces of charcoal contained in receivers, inverted in lime-water, and filled with inflammable or nitrous air, or any kind of diminiſhed air, and conſequently unfit to aſſiſt combuſtion, no lime was precipitated[*]. "This," *ſays the Doctor*, "furniſhes another, and, "I think, a pretty deciſive proof, that, in the precipitation "of lime by charcoal, the fixed air does not come from the

[*] Exper. and Obſer. vol. i. p. 136.

" charcoal, but from the common air. Otherwiſe it is hard
" to aſſign a reaſon, why the ſame degree of heat (or at leaſt
" a much greater) ſhould not expel the fixed air from this
" ſubſtance, though ſurrounded by thoſe different kinds of
" air, and why the fixed air might not be tranſmitted through
" them to the lime-water."

Thus the Doctor ſeems inclined to think, that a quantity of fixed air exiſts in common reſpirable air, which, in the act of combuſtion, is ſeparated from it. But yet it ſeems not improbable, that the fixed air may be formed by the combination of part of the phlogiſton diſcharged from the burning body, with ſome other principle exiſting in common air; for we are, as yet, uncertain whether fixed air is a ſimple or a compound ſubſtance; but we ſhall examine this ſubject more particularly when we come to treat of the nature of fixed air.

The calcination of metals and ſemi-metals, being a phlogiſtic proceſs, requires the preſence of common or reſpirable air; without which it cannot be effected. A metallic ſubſtance confined in a quantity of air, and there ſufficiently heated by a burning lens, or otherwiſe, is calcined, viz. it loſes its metallic appearance, and is reduced into a calx, in which ſtate it is heavier than when it was in a metallic form. The air, at the ſame time, becomes phlogiſticated, viz. unfit for reſpiration, combuſtion, &c. and is diminiſhed in bulk; but, different from the air phlogiſticated by burning bodies, it does not occaſion any precipitation of lime in lime-water.

The calcination of metals in a given quantity of air is limited, ſo that it cannot be carried on beyond a certain degree, which is proportionate to the quantity and purity of the air employed. Thus that excellent philoſopher, Father Beccaria, having incloſed lead and tin filings in veſſels which were afterwards ſealed hermetically, and in this manner having expoſed them to a ſufficient degree of heat, obſerved that a part only of the ſaid metals could be calcined, which part was greater or leſs according to the greater or leſs quantity of air contained in the veſſels*.

Mr. Lavoisier alſo endeavoured to calcine metals in confined air, by means of a large burning-glaſs, which was not leſs than 33 inches in diameter; and found that only a ſmall quantity of metal was calcined during the firſt 4 or 5 minutes; after which, the continuation of that intenſe heat, even for half an hour, had no other effect, than that of keeping the metal in a fluid ſtate †.

The remarkable phenomenon of the metals acquiring weight by calcination, and of the air being at the ſame time diminiſhed in bulk, may naturally induce one to ſuſpect, that the metals abſorb part of the air in the act of calcination; but the well-contrived and accurate experiments of Mr. Lavoisier put this matter out of all doubt. Indeed, one Jean Rey, in an eſſay written expreſsly on the ſubject, in the year 1630, was the firſt who attributed the acquiſition of weight, by calcining metallic ſubſtances, to the abſorbtion of air. He ſuppoſes, that only the denſer part of the air adheres to the metallic calxes, while the more ſubtile aërial particles are ſeparated from it in the act of calcination. Dr. PRIESTLEY, having ſuſpended pieces of tin and of lead in given quantities of air, and having directed the focus of a burning lens upon them, obſerved that the air was thereby diminiſhed of one fourth; in which diminiſhed ſtate it did not effervefce with nitrous air, it was noxious to animals, and it was incapable of being farther diminiſhed by a mixture of iron-filings and brimſtone; which compoſition, being a real, though ſlow kind of calcination, does alſo diminiſh reſpirable air. Waſhing, or agitating in water, the Doctor obſerves, purified, in great meaſure, this contaminated air. In this experiment the air was obſerved to be equally affected by the calcination of tin or lead; in both which caſes the water, in which the receivers were inverted, acquired a yellowiſh tinge, and that a thin whitiſh pellicle covered the ſurface of it, as well as the ſurface of the receivers. When the receivers were inverted in lime-water, inſtead of common water, no precipitation took place, though the lime-water acquired a peculiar ſmell, as well as taſte and colour. When the receivers were inverted in quickſilver, the diminution of the air occaſioned by the calcination was only of one fifth; and by admitting water above the ſurface of the quickſilver, no farther diminution of the air enſued. Hence the Doctor is led to ſuppoſe, that the ſubſtance abſorbed by the metallic calxes is fixed air.—We ſhall obſerve hereafter, that this conſequence does not neceſſarily follow.

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* Mem. de l'Academy de Turin, ii.

† Lavoisier's Eſſays, part ii. chap. vi.

Dr. PRIESTLEY having attempted to calcine metals in fixed air, inflammable air, and other kinds of elaſtic fluids that were quite unfit for reſpiration and combuſtion, could not accompliſh it; though he remarks that a ſlight calcination of metal can take place in air phlogiſticated by burning charcoal. "It ſhould ſeem," *ſays he*, "that phlogiſton is re-"tained more obſtinately by charcoal, than it is by lead or "tin; for, when any given quantity of air is fully ſaturated "with phlogiſton from charcoal, no heat, that I have yet "applied, has been able to produce any more effect upon it; "whereas, in the ſame circumſtances, lead and tin may ſtill "be calcined, at leaſt be made to emit a copious fume, in "which ſome part of the phlogiſton may be ſet looſe.

"The air, indeed, can take no more; but the water "receives it, and the ſides of the phial alſo receive an ad-"dition of incruſtation. This is a white powdery ſubſtance, "and well deſerves to be examined[*]."

Mr. LAVOISIER, undertaking to examine this ſubject with the moſt ſcrupulous attention, begins his experimental inquiry from the following general obſervations. "Firſt," *ſays he*, "The calcination of metals cannot take place in "veſſels cloſely ſtopped, and exhauſted of air. Secondly, It is "proportionably the more readily performed, as a greater

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[*] Exper. and Obſer. vol. i. part i. ſect. 8.

" extent of ſurface in the metal is expoſed to the air. " Thirdly, It is a fact known to all the metallurgiſts, and " obſerved by all thoſe who have been converſant in the " operations of aſſaying metals, that in every reduction, there " is an effervefcence at the moment the metallic ſubſtance " paſſes from the ſtate of a calx to that of a metal; now an " effervefcence is commonly no more than a ſeparation of " elaſtic fluid; the calx therefore contains an elaſtic fluid, " under a fixed form, which recovers its elaſticity at the " inſtant of reduction †."

The firſt object of his experiments was, to demonſtrate the exiſtence of a certain ſubſtance in metallic calxes, which aſſumed the form of permanently elaſtic fluid, when thoſe calxes were reduced. To this effect, he reduced ſome minium, or red lead, under a receiver inverted in water ‡, by mixing it with powdered charcoal, and heating it by means of a large burning-glaſs; he alſo reduced the minium, by the addition of charcoal, in an iron retort, the mouth of which went under a glaſs receiver filled with and inverted in water, the retort being heated in a common furnace; and he reduced it alſo in a new and clean gun-barrel, uſing it inſtead of the retort: by which experiments he conſtantly found that a quantity of elaſtic fluid was produced, which was proportionable to the quantity of reduced metallic calx. The following is the calculation of one of his experiments; the reſults of the reſt importing nearly the ſame.

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† Eſſays Phyſical and Chemical, part ii. chap. v.

‡ Mr. Lavoisier uſed to introduce a ſmall quantity of oil upon the ſurface of the water within the inverted receiver, in order to prevent the elaſtic fluid having immediate contact with the water, or being abſorbed by it.—This oil he introduced by means of an incurvated funnel, Plate III. fig. 7. the uſe of which may be conceived by merely inſpecting the figure.

	oz.	dra.	gr.
Of minium	6	0	0
Of charcoal powdered and ſifted	0	6	0

Theſe ingredients were put into the iron retort, in order to reduce the metallic calx; and after the reduction, the whole reſiduum that was taken out of the retort, viz.

The lead and ſome charcoal, weighed	5	7	66
Conſequently they had loſt by the reduction	0	6	6

The quantity of elaſtic fluid produced in this reduction was 560 cubic inches; but the bulk of the reduced lead was about $\frac{3}{4}$ of a cubic inch; therefore minium contains a quantity of elaſtic fluid 747 times the bulk of the metal out of which it originated.

Conſidering that the loſs of weight, in this reduction, was only ſix drachms and ſix grains, and that the quantity of produced elaſtic fluid was 560 cubic inches, this elaſtic fluid could not be atmoſpheric air; for 560 cubic inches of it would have weighed about 3 drachms and 41 grains; it muſt therefore be an elaſtic fluid ſpecifically heavier than common air. Upon the ſuppoſition that this diſcharged elaſtic fluid was as heavy as calcareous gas, or fixed air, 560 cubic inches of it would have weighed leſs than 6 drachms and 6 grains. But the author attributes this want of weight principally to a ſmall quantity of phlegm, which is contained in minium, and which he found, by making the experiment with a common apparatus for diſtillation, was ſeparated from it in the act of reduction.

Leſt the production of elaſtic fluid, in the reduction of minium by the addition of charcoal, ſhould be attributed to the charcoal rather than to the minium, the ingenious author heated charcoal only in the clean gun-barrel, the mouth of which went under the inverted receiver as uſual; but found that the elaſtic fluid yielded by this ſubſtance was very ſmall: ſo that the production of elaſtic fluid, in the above-mentioned experiment of the reduction of minium, muſt be almoſt entirely attributed to the minium.

Mr. LAVOISIER next proceeds to demonſtrate, experimentally, the reverſe of the above-eſtabliſhed law, viz. that whenever metals are calcined, an abſorbtion of elaſtic fluid takes place, and that the calcination is nearly proportional to that abſorbtion *. Having calcined tin and lead, both ſeparately and together, under a receiver inverted in water, by means of the large burning-glaſs mentioned before; and after that as much of the metal was calcined as it was poſſible in that confined quantity of air, he obſerved, when the apparatus was perfectly cool, that an abſorbtion of part of the air

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* Mr. LAVOISIER was firſt of opinion, that the elaſtic fluid abſorbed by metallic calxes, in the act of calcination, was the ſame that eſcaped from it in the act of reduction, namely, *fixed air*; but farther experiments afterwards obliged him to alter his opinion.—Eſſays Phyſical and Chemical.

was manifeſted by the water, whoſe ſurface had aſcended above the place it ſtood at before the calcination. When Mr. Lavoisier calcined the lead under a receiver inverted in mercury, he found that the abſorbtion of elaſtic fluid was juſt equal to one twentieth of the air contained under the receiver, and that the weight of this abſorbed quantity of elaſtic fluid was exactly proportionate to the augmentation in weight of the metallic calx.

Having moiſtened ſome iron filings with diſtilled water, and having introduced them under an inverted receiver, Mr. Lavoisier obſerved, that the bulk of the air within the receiver diminiſhed in proportion as the filings became more and more ruſty; but at the end of two months the abſorbtion, which amounted to one fourth of the air contained in the receiver, ceaſed. Air thus diminiſhed was obſerved by Dr. Priestley to be not diminiſhable farther by nitrous air †.

Notwithſtanding the conviction which thoſe experiments ſeems to be attended with, Mr. Lavoisier, in order to avoid any poſſible objection that might be offered againſt the above-mentioned theory of the metallic calxes, made the following ingenious experiment:—He weighed a quantity of tin, and alſo a glaſs retort; then putting the tin into the retort, ſealed the mouth of it hermetically. In this manner he expoſed the apparatus to a proper degree of heat, in order to calcine the tin; but the calcination was ſoon ſtopped; the quantity of air incloſed in the retort being not ſufficient to aſſiſt the calcination of all the quantity of tin; then the ingenious philoſopher, intermitting the operation, weighed the ſealed retort with the partly-calcined tin in it, and found that the total weight was the ſame as before; but having broke open the retort, and taken the partly-calcined tin out of it, weighed them both ſeparately, and found that the retort weighed exactly as much as before, but the tin was increaſed in weight; this increaſe of weight, therefore, was certainly owing to the abſorbtion of air *. Thus it was compleatly demonſtrated that the air, which had long been conſidered as a neceſſary though mechanical agent in this proceſs, was a neceſſary chemical ingredient, part of which was abſorbed by the calx of a metal, whilſt the other part was combined with the phlogiſton which eſcaped from the metal in the proceſs of calcination.

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† Exper. and Obſer. vol. ii. p. 182.

The nature of this elaſtic fluid, diſcharged by metallic calxes, remains to be examined; but this will be done in a more proper place of this work.

Beſides the above-mentioned particular proceſſes, air is contaminated and diminiſhed by the action of various other ſubſtances, viz. by ſulphur, by lime mixed with water, by lime mixed with ſalt ammoniac, by lime mixed with acids, by iron mixed with volatile alkali, by copper mixed with

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* Hiſt. de l'Acad. pour l'Anné 1774.

volatile alkali, by lead mixed with vinegar, by liver of ſulphur, and others, which we ſhall examine gradually. In this phenomenon of the air being diminiſhed, it muſt be generally obſerved, that the diminution of the air is always attended with a contamination of the ſame; ſo that air which has been diminiſhed by any proceſs, muſt be conſidered to be much leſs pure than it was before its having been diminiſhed: and when a quantity of air has been ſo far diminiſhed, that it is no longer diminiſhable by thoſe proceſſes which are wont to diminiſh common air, it ſhould then be conſidered to be very impure, and unfit for reſpiration, for combuſtion, &c. every experiment hitherto made ſeeming to eſtabliſh this law. Indeed, in ſome caſes, the diminution of the air is not proportionate to the degree of its contamination; thus air in which charcoal is extinguiſhed is diminiſhed ſurpriſingly, yet the remaining quantity of it is not found to be more noxious than when it is acted upon by various other ſubſtances, which do not diminiſh it nearly ſo much. This, however, is owing to a remarkable property of charcoal, which is that of abſorbing a prodigious quantity of air, of which we ſhall take particular notice in the next Part of this book. Thus, alſo, air is abſorbed by water, &c.

It was common among the philoſophers of the laſt age to ſay, when air had been diminiſhed by combuſtion, reſpiration, or other proceſs, that its ſpring was weakened; by which they meant, that the repulſion between the particles of air being diminiſhed, the uſual preſſure of the atmoſphere confined it in a ſmaller ſpace, viz. *diminiſhed* it. From this ſuppoſition it muſt neceſſarily follow, that diminiſhed or contaminated air ſhould be ſpecifically heavier than common air; but ſeveral accurate experiments, lately made, ſhew that phlogiſticated air is ſpecifically lighter than good common air; hence the old opinion of the air's elaſticity being weakened muſt be rejected, and its diminution muſt be attributed to ſome other cauſes; which in general may be conſidered to be either the abſorbtion of air by the very ſame ſubſtances which phlogiſticate it, or to the ſeparation of fixed air from it, or of that ſubſtance, whatever it is, which forms the fixed air obtained in ſeveral caſes in which the air is diminiſhed, and which fixed air, conſidered by itſelf, is much heavier than common air. Phlogiſtication, then, is ſo far from diminiſhing the elaſticity of the air, and rendering it ſpecifically heavier, that, on the contrary, phlogiſticated air is ſpecifically lighter than common air. Dr. PRIESTLEY, ſpeaking of the air in which candles or brimſtone had burned out, ſays, "After making ſeveral "trials for this purpoſe, I concluded that air, thus diminiſhed "in bulk, is rather lighter than common air; which favours "the ſuppoſition of the fixed air, or heavier part of the "common air, having been precipitated [*]."

And in another place, he ſays, "My readers will have "obſerved, that not only is common air liable to be di-

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[*] Exper. and Obſer. vol. i. p. 46.

" miniſhed by a mixture of nitrous air, but likewiſe air " originally produced from inflammable air, and even from " nitrous air itſelf, which never contained any fixed air. " From this it may be inferred, that the whole of the " diminution of common air by phlogiſton is not owing to " the precipitation of fixed air, but from a real contraction " of its dimenſions, in conſequence of its union with phlo- " giſton. Perhaps an accurate attention to the ſpecific " gravity of air procured from theſe different materials, and " in theſe different ſtates, may determine this matter, and " aſſiſt us in inveſtigating the nature of phlogiſton.

" In what *manner* air is diminiſhed by phlogiſton, inde- " pendent of the precipitation of any of its conſtituent parts, " is not eaſy to conceive; unleſs air thus diminiſhed be " heavier than air not diminiſhed, which I did not find to " be the caſe. It deſerves, however, to be tried with more " attention. That phlogiſton ſhould communicate abſolute " *levity* to the bodies with which it is combined, is a " ſuppoſition that I am not willing to have recourſe to, " though it would afford an eaſy ſolution of this dif- " ficulty *."

Dr. PRIESTLEY, in his firſt experiments on the ſpecific gravity of elaſtic fluids, made uſe of a Florence-flaſk, into which the required elaſtic fluid was introduced by firſt filling the flaſk with water, in the uſual manner; then he weighed the flaſk, with the contained elaſtic fluid, in a pair of ſcales. But the Doctor, juſtly obſerving the errors to which this method might be ſubject, ariſing from the drops of water which adhere to the inſide of the flaſk, ſubſtituted a bladder. "But," *ſays he*, "though this cannot be done with pre-"ciſion in a bladder, as uſed by Mr. CAVENDISH, becauſe "the degree of diſtention cannot be meaſured with much "accuracy, yet this circumſtance is more than counter-"balanced by being able to change the air, with compreſſing "the bladder, without wetting it.

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* Exper. and Obſer. vol. i. p. 267.

"I therefore took a glaſs tube, about nine inches long, and "faſtened it to the neck of a bladder, which, with ſuch a "degree of diſtention as I could give it, in the manner in "which the experiment was made, contained fifty-five ounce "meaſures, or one penny-weight nine grains, of common air. "The tube was ſo faſtened, that I could take it out at "pleaſure; and having the bladder thus prepared, I care-"fully compreſſed it, then filling it in part with that kind of "air which I was about to weigh, I compreſſed it again, and "then filled it intirely; ſo that I was pretty confident that "the air within the bladder contained very little common, "or any other kind of air. In this manner I proceeded to "weigh *dephlogiſticated air*, and at the ſame time *nitrous air*, "and *air phlogiſticated with iron filings and brimſtone*, which "I take for granted is the ſame thing with air phlogiſticated "by any other proceſs.

“ The following ſhort table exhibits the reſult of all theſe “ experiments at one view *.

	dwts.	gr.
“ The bladder filled with phlogiſticated air weighed - - - -	7	15
“ ——————— nitrous air -	7	16
“ ——————— common air -	7	17
“ ——————— dephlogiſticated air	7	19

Mr. FONTANA, towards the latter end of the year 1779, communicated to me a method of determining the ſpecific gravities of different elaſtic fluids, which he had very lately uſed, and which is certainly ſuperior to any other practiſed before. This method is as follows:—H fig. IX, of plate III. is a globular glaſs veſſel, of about four inches in diameter, to whoſe neck a metal ſtop-cock is cemented. The aperture, which, through the ſtop-cock, communicates with the inſide of the veſſel, is very ſmall, as about one fortieth of an inch, or rather leſs, and the whole is made very light. D F is a glaſs veſſel, to the open top of which another ſtop-cock is fitted, to which the veſſel H is adapted by a ſcrew. The aperture through the ſtop-cock D, of the receiver D F, is alſo very narrow. Now ſuppoſe that a given elaſtic fluid is required to be weighed with this inſtrument, for inſtance fixed air. Firſt, the receiver D F, having the ſtop-cock D cloſed, is filled with mercury, and inverted in a baſin containing alſo

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* Exper. and Obſer. vol. ii. p. 93.

mercury; then the fixed air is introduced into it after the uſual manner, which occupying the upper part of the receiver, will depreſs the quickſilver as at F. The quantity of elaſtic fluid thrown into this receiver ſhould be more than that which is ſufficient to fill the veſſel H. This done, the veſſel H muſt be ſcrewed to a good air-pump *, and the air muſt be exhauſted from it; after which the ſtop-cock is to be cloſed, and the exhauſted veſſel being removed from the air-pump, muſt be ſcrewed to the ſtop-cock D, in the ſituation repreſented by A B. Now both the ſtop-cocks C and E being opened, the fixed air contained in the receiver D F will ruſh into the veſſel A. In order to avoid the error, which might ariſe from the pillar of mercury in the veſſel D F, this veſſel ſhould now be lowered ſo far into the quickſilver of the baſin G, that the ſurface of the quickſilver F might coincide with the ſurface of the quickſilver in the tub; then the ſtop-cock C being cloſed, the veſſel A is unſcrewed from the veſſel D F, and is weighed in a nice pair of ſcales. It is plain, that if from this weight, the weight of the veſſel A, weighed when exhauſted of air, be ſubtracted, the remainder will be the weight of the fixed air; which being divided by the number of cubic inches, to which the capacity of the veſſel is equal, the quotient is the weight of one cubic inch of fixed air †. Thus Mr.

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* The beſt air-pumps now made, are thoſe conſtructed after the principle of Mr. Smeaton. See a deſcription of it in the Phil. Tranſ. vol. xlvii.

† The quantity of common air which always remains in the veſſel H, even when

Mr. Fontana tried the weight of all the known elaſtic fluids, and found, that air phlogiſticated by ſaturation with nitrous air is ſpecifically lighter than common air; for, according to his obſervations, a cubic inch of the former weighed $\frac{377}{1000}$ of a grain; whereas a cubic inch of the latter weighed $\frac{385}{1000}$ of a grain. Theſe experiments were made when the barometer was at a mean height, and the thermometer ſtood at temperate.

This accurate method, therefore, ſeems to put it out of all doubt, that phlogiſticated air is lighter than common air. Probably the ſpecific gravity of phlogiſticated air is different, according to the various cauſes that phlogiſticate the air, but this has not yet been aſcertained.

Lime, when mixed with water, was obſerved by Dr. Hales to injure common air; but I remember that Mr. Fontana, ſome time ago, ſlacked a quantity of quick-lime by mixing it with water under an inverted receiver, which was attended with heat, ebullition, and hiſſing, as uſual; however, the air of the receiver was very little affected by it. Indeed I ſay very little affected, becauſe, by the taſte of nitrous air, it appeared to be nearly as capable of diminution as the other air of the room; yet it is known, from common experience, that to breathe air impregnated with particles of lime is injurious to the animal body. This is one of the inſtances

when a very good air-pump is uſed, is too ſmall to occaſion any ſenſible error. Beſides, it is a conſtant quantity, which can in no caſe alter the comparative gravities of the different elaſtic fluids.

which ſhew that the taſte of nitrous air is inſufficient to manifeſt the wholeſomeneſs of the air in every caſe, eſpecially when the noxious particles cannot properly be ſaid to be combined with the air, but only float in it, as it is evident from their ſubſiding after a certain time. Dr. PRIESTLEY obſerved, that a quantity of air in a week's time was not ſenſibly affected by quick-lime. The receiver containing the air and the lime was inverted in mercury *.

Dr. HALES, in his admirable book, entitled, *The Vegetable Statics*, remarks various ſubſtances which diminiſh, and conſequently contaminate, or, as he ſays, *abſorb* air. The principal of theſe are the following; which, for clearneſs ſake, I ſhall expreſs in the form of a table.

Materials uſed.	Cubic inches of air abſorbed.
A quarter of an inch of iron filings and one cubic inch of powdered ſulphur — —	19
A cubic inch of aqua-fortis on an equal quantity of powdered marcaſite or Walton pyrites	85
A cubic inch of aqua-fortis, with an equal quantity of pit-coal, in three days — —	18
But in three days more remitted and generated 12 cubic inches.	
Two cubic inches of quick lime with four of vinegar — — — —	22
Two cubic inches of lime and as much ſal ammoniac — — — —	115

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* Exper. and Obſer. vol. ii. p. 184.

By the burning of linen rags dipped in melted ſulphur, in a large veſſel — —	198
In a ſmaller veſſel — — —	150
Two grains of Runkel's phoſphorus — —	28

The Doctor alſo obſerves, that air is injured by a mixture of volatile alkali mixed with iron, or with copper, by the diſtillation of aqua-fortis*, and by the ſublimation of ſulphur, or of volatile ſal ammoniac.

This ingenious author was the firſt who obſerved the diminution of a mixture of nitrous with common air; which property Dr. Priestley afterwards uſed as a teſt of the wholeſomeneſs of air.

The reader will naturally remark, in the above-mentioned obſervations of Dr. Hales, that the diminution was generally occaſioned by a diſcharge of phlogiſton, which evidently took place in thoſe experiments.

Since Dr. Hales's time, ſeveral of thoſe effects on reſpirable air have been more ſatisfactorily examined.

Air, in which animal ſubſtances are left to putrefy, loſes its property of aſſiſting reſpiration, combuſtion, and the other proceſſes, for which common air is wont to be neceſſary. Dr. Priestley obſerves, that air tainted with animal or vegetable ſubſtances, has the ſame properties with air tainted by animal reſpiration; for they equally extinguiſh flame, are noxious to animals, have the ſame offenſive ſmell, precipitate lime in lime-water, and are reſtored by the ſame means. It is, however, to be obſerved, that the air may be tainted by putrefaction in a much greater degree than by reſpiration. When an animal is left to putrefy in a quantity of air, the bulk of the air generally increaſes for a few days, owing to ſome elaſtic fluid that is diſcharged from the body of the animal; but after a certain time, the length of which principally depends upon the ſtate of the body of the animal and the temperature of the apparatus, the whole quantity of air will be found to diminiſh gradually to a certain degree. Here it is proper to obſerve, that this phenomenon is ſubject to various alterations, moſtly owing to the quantity of the air and of the animal ſubſtance employed. For inſtance, if you put about half a pound of fleſh, or more, into an inverted receiver, which contains two or three ounce meaſures of air, the bulk of the elaſtic fluid will certainly increaſe in this caſe, becauſe ſome elaſtic fluid is produced, which is greater in quantity than the diminiſhed portion of that quantity of common air that is contained in the receiver.

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* Dr. Priestley has obſerved, that ſmoking ſpirit of nitre phlogiſticates common air; but that when the nitrous acid contains little phlogiſton, it then takes ſome from the air, and conſequently contributes to mend it a little, and that in a certain ſtate, it will not produce any ſenſible effect upon it. *Exp. and Obſer.* vol. iii. ſect. viii.

Dr. Priestley obſerves, that the elaſtic fluid diſcharged from putrefying ſubſtances "ſeems, in ſome caſes, to be "chiefly fixed air, with the addition of ſome other effluvium, "which has the power of diminiſhing common air."

The Doctor having put a dead mouſe into a receiver filled with and inverted in quickſilver, obtained a quantity of elaſtic fluid, which he expoſed to a quantity of lime-water; and at the ſame time he alſo expoſed a like quantity of fixed air to a like quantity of lime-water in a ſimilar manner; and obſerved, that by both elaſtic fluids the lime-water was rendered alike turbid, that it roſe in the receivers equally high, and that about the ſame quantity of either elaſtic fluid remained unabſorbed; which ſhews the great reſemblance between fixed air and the elaſtic fluid produced by putrefaction of animal ſubſtances. But the Doctor remarks, that one "of theſe kinds of air," viz. the fixed air, "was exceedingly "ſweet and pleaſant, and the other inſufferably offenſive; "one of them alſo would have made an addition to any "quantity of common air, with which it had been mixed, "and the other would have diminiſhed it.

"Putrid cabbage," *he adds*, "green or boiled, infects the "air in the very ſame manner as putrid animal ſubſtances *." The ſame thing may be ſaid of air in which other vegetable ſubſtances are left to putrefy. Freſh meat, even without the leaſt ſign of putridity, phlogiſticates common air conſiderably, and in a ſhort time.

Common experience ſhews, that freſh paint, made of white lead and oil, is offenſive; ſo that judicious perſons generally avoid ſleeping in rooms newly painted. Dr. PRIESTLEY examining this matter, found that common air was really injured by that mixture, as alſo by the common red-lead paint; for having daubed ſome pieces of paper with the ſaid paints, and having put them under receivers, he obſerved that the air within the receivers was diminiſhed between one fifth and one fourth in about twenty-four hours. On examination, it was found to be highly noxious, it being not diminiſhed farther by nitrous air, or by a mixture of iron-filings and brimſtone.

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* Exper. and Obſer. vol. i. part i. ſect. 4.

When braſs-duſt, inſtead of ſteel or iron-filings, is mixed with brimſtone, and the mixture is expoſed to a given quantity of air, Dr. PRIESTLEY obſerves that the air is neither increaſed nor diminiſhed in bulk by it; but it extinguiſhes flame.

The following obſervations on the diminution of air by various proceſſes are alſo of Dr. PRIESTLEY.

Liver of ſulphur diminiſhes common air of about one fifth, and renders it highly noxious.

A cement made with equal parts of common coarſe turpentine and bees-wax, diminiſhes the air of about one ſixth.

This ſame ſort of cement, when made with a finer ſort of turpentine, and alſo the common red cement *, diminiſh the air in a very ſmall degree.

Oil of turpentine has the remarkable property of phlogiſticating common air, and at the ſame time of abſorbing a

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* This cement, which is commonly uſed for electrical purpoſes, is made of bees-wax, roſin, and the powder of red oker.

great quantity of it. If the oil of turpentine has abſorbed as much air as it can, then the effects produced by it upon more air, to which it is expoſed, is only the phlogiſtication of the ſame, and the ſmall diminution, which is the reſult of that phlogiſtication; otherwiſe the oil of turpentine, when deprived of air, as it may be done by means of an air-pump, both phlogiſticates the air, and abſorbs or diminiſhes it more than is effected by any other phlogiſtic proceſs*. Says Dr. PRIESTLEY "I have one memorandum of a quantity of "oil of turpentine abſorbing five ſixths of a quantity of "common air †."—Mr. BOYLE relates, that a quantity of "air was totally abſorbed by a mixture of oil of turpentine "and ſpirit of wine ‡."

Oil of mint and oil of cinnamon do alſo phlogiſticate the air. Common air, when agitated in ſpirit of wine, becomes phlogiſticated in a ſmall degree. "Upon the "whole," *ſays Dr.* PRIESTLEY, "the effect of ſpirit of "wine ſeems to be very nearly the ſame with that of *water* "upon common air, which is, reducing it to a certain ſtandard, by depriving good air, and mending the bad, ſo as to "bring both of them a little lower than the ſtandard of "common air. Accordingly I found, that when I agitated "a quantity of common air, phlogiſticated with nitrous air,

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* Charcoal abſorbs a much greater quantity of air than oil of turpentine.

† Exper. and Obſer. vol. ii. ſect. 7.

‡ BOYLE's Works, vol. v. p. 113.

" in ſpirit of wine, it was evidently mended, but not more " than it would have been by agitation in water *."

Nitrous ether injures common air, but *vitriolic ether* does not phlogiſticate the air; which ſeems very remarkable, when we conſider that it is a very volatile and inflammable fluid. When a ſmall quantity of vitriolic ether is put into a receiver filled with air and inverted in water, the bulk of the air is increaſed, and about doubled, on account of the elaſticity of the ether; but after ſome time the water abſorbs the ether, and the air remains in the ſtate it was before. By nitrous ether the bulk of air is increaſed of about one ſixth only †.

Quickſilver, when heated in ſuch a degree as to become a vapour, phlogiſticates the air in a ſmall but ſenſible degree.

Mr. CANTON's phoſphorus, and the Bolonian ſtone, were obſerved, by Mr. FONTANA, to phlogiſticate common air in a ſmall degree; but Mr. VOLTA obſerves, that the latter, when good, produces this effect very quick, though the former not ſo eaſily.

KUNKEL's phoſphorus diminiſhes and contaminates the air in a very great degree. Indeed, when the phoſphorus, in its natural ſtate, is expoſed to a quantity of common air, it phlogiſticates the air very ſlowly; but when burning, it occaſions a very conſiderable phlogiſtication and abſorbtion of air. Mr. LAVOISIER, who has made ſeveral accurate experiments relating to this ſubject, has aſcertained the following particulars; viz. When phoſphorus is fired, by means of a lens,

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* Exper. and. Oſerv. vol. ii. ſect. 7.

† Ether has the ſame effect with other elaſtic fluids.

under

under a receiver inverted in water, upon the ſurface of which is a ſmall quantity of oil, or in quickſilver, the diminution of the air is ſomething leſs than three cubic inches for every grain of phoſphurus burned. In a quantity of air equal to 109 cubic inches, about ſix or ſeven grains of phoſphorus can only be burned. The phoſphoric acid will be found to be heavier than the phoſphorus itſelf before combuſtion; or, which is the ſame thing, a quantity of phoſphorus after combuſtion, will be found to be heavier than before; and, as the common air is diminiſhed by the combuſtion of this ſubſtance, it is natural to ſuppoſe that the increaſe of weight is owing to the abſorbtion of air; but the weight acquired by the burned phoſphorus, is greater than the weight of the diminiſhed portion of the air; therefore it follows, that in the act of combuſtion the phoſphorus muſt imbibe the heavier part of common air. This matter abſorbed from the air Mr. LAVOISIER proves to be not water, becauſe air in which phoſphorus had been burned was not meliorated ſo as to aſſiſt the farther combuſtion of phoſphorus, nor did it acquire the loſt bulk by the vapour of diſtilled water; and alſo by examining the ſpecific gravity of the phoſphoric acid, becauſe this was found to have acquired or imbibed from the air ſomething ſpecifically heavier than water †.

Air is injured by being expoſed to the effluvium of liquid vegetable acid or concentrated vinegar. ‡.

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† Eſſays Phyſical and Chemical.

‡ Exper. and Obſerv. vol. i. p. 27.

There are various other proceſſes which phlogiſticate common air, and which might here be enumerated; ſuch is the firing of gunpowder, the expoſing diamonds to an intenſe heat *, the burning of charcoal, &c.; but it ſeems unneceſſary to detain the reader with the account of all thoſe particulars, ſince they are all comprehended under the general head of combuſtion, which has been already ſufficiently examined. Some of thoſe proceſſes are indeed attended with peculiar phenomena; as the production of an elaſtic fluid by gunpowder, the abſorbtion of air and other elaſtic fluids by red-hot charcoal, and others; but thoſe will be conſidered in other places.

The electric ſpark, when taken repeatedly in a quantity of common air, phlogiſticates it very ſenſibly; but as this effect, if attributed intirely to the electric fluid itſelf, would ſhew ſome degree of identity between that fluid and the inflammable principle (which, on other accounts, ſeems rather improbable) it is here neceſſary to examine this matter ſomewhat more particularly. Dr. PRIESTLEY, who ſeems to have been the

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* It is but a few years ago ſince it was clearly demonſtrated in France, that a diamond is a combuſtible ſubſtance; ſo that when acted upon by a violent heat, in the free air, it flames and conſumes like any other combuſtible body. See ROZIER's Journal, and MACQUER's Dict. of Chemiſtry, art. Diamonds.—Mr. LAVOISIER having thrown the focus of a large burning-glaſs upon four grains and a half of diamonds, which were kept under a receiver containing 60 cubic inches of air, found that after 16 minutes the air had ſuffered a diminution of nearly one eighth, and the remainder precipitated the lime in lime-water. See Mem. de l'Acad. des Sciences à Paris, for the year 1772.

firſt

firſt perſon that obſerved the diminution of air occaſioned by electric ſparks, made uſe of the following inſtrument, viz. a glaſs tube, to one end of which a wire was cemented, which being fixed in the axis of the tube, projected a ſhort way within it, and on its outward extremity was furniſhed with a knob. The air was introduced into the tube, whoſe open end was inverted in a baſin of mercury, or other fluid, and the lower part of the tube was alſo filled with that fluid; the ſparks then being taken upon the knob of the wire, by approaching it to the conductor of an ordinary electrical machine, paſſed from that extremity of the wire which was within the tube, through the air contained in it, to the fluid under it. When common air was contained in the tube, and the liquor uſed was water tinged blue, or rather purple, with the juice of turnſole, or archil, by taking ſparks for about two minutes the liquor was rendered manifeſtly red.

" The moſt important," *obſerves the Doctor*, " though " the leaſt expected obſervation, however, was, that, in pro- " portion as the liquor became red, it advanced nearer to the " wire, ſo that the ſpace of air in which the ſparks were taken " was diminiſhed; and at length I found that the diminu- " tion was about one fifth of the whole ſpace; after which, " more electrifying produced no ſenſible effect.

" To determine whether the cauſe of the change of colour " was in the *air*, or in the *electric matter*, I expanded the " air, which had been diminiſhed in the tube by means of an " air-pump, till it expelled all the liquor, and admitted freſh

" blue liquor into its place; but after that, electricity produced no ſenſible effect, either on the air, or on the liquor; " ſo that it was evident that the electric matter had decompoſed the air, and had made it depoſit ſomething that " was of an acid nature.

" In order to determine whether the *wire* had contributed " any thing to this effect, I uſed wires of different metals, " iron, copper, braſs, and ſilver; but the reſult was the very " ſame with them all.

" It was alſo the ſame when, by means of a bent glaſs " tube, I made the electric ſpark without any wire at all, in " the following manner:—Each leg of the tube (*fig.* 20 *of* " *plate* III.) ſtood in a baſin of quickſilver; which, by means " of an air-pump, was made to aſcend as high as *a*, *a*, in " each leg, while the ſpace between *a* and *b* in each contained the blue liquor, and the ſpace between *b* and *b* " contained common air. Things being thus diſpoſed, I " made the electric ſpark perform the circuit from one leg to " the other, paſſing from the liquor in one leg of the tube " to the liquor in the other leg, through the ſpace of air. " The effect was, that the liquor, in both the legs, became " red, and the ſpace of air between them was contracted, as " before.

" Air thus diminiſhed by electricity makes no efferveſcence " with, and is no farther diminiſhed by a mixture of nitrous " air; ſo that it muſt have been in the higheſt degree " noxious, exactly like air diminiſhed by any other proceſs.

" In order to determine what the *acid* was, which was " depoſited by the air, and which changed the colour of the " blue liquor, I expoſed a ſmall quantity of the liquor ſo " changed to the common air, and found that it recovered " its blue colour, exactly as water, tinged with the ſame " blue, and impregnated with fixed air, will do. But the " following experiment was ſtill more deciſive to this pur" poſe :—Taking the electric ſpark upon *lime-water*, inſtead " of the blue liquor, the lime was precipitated as the air " diminiſhed.

" From theſe experiments it pretty clearly follows, that " the electric matter either is, or contains phlogiſton; ſince " it does the very ſame thing that phlogiſton does. It is " alſo probable, from theſe experiments, that the ſulphurous " ſmell, which is occaſioned by electricity, being very dif" ferent from that of fixed air, the phlogiſton in the electric " matter itſelf may contribute to it *."

The Doctor found, that the diminution of common air by this means was about one fourth of the whole quantity. If the air was confined in the tube by quickſilver, inſtead of the blue liquor, the electric ſparks diminiſhed it, and if the blue liquor was afterwards introduced to this diminiſhed air, it became red, though not very quick †.

Notwithſtanding the numerous and well-contrived experiments of Dr. PRIESTLEY, concerning this ſubject, the conſequence, that the electric fluid either is or contains phlogiſton, does not ſeem to follow very evidently; for, conſidering that the wire belonging to the inſtrument uſed by him was faſtened by *cement*, which ſubſtance the Doctor himſelf has found to phlogiſticate common air when not acted upon by any electric power whatever; and it is natural to ſuppoſe that this cement would be capable of phlogiſticating the air much more eaſily when electricity is uſed; the lateral ſhock, or ſome effect of it, does certainly act upon the cement, though the main ſhock, or the quantity of electric fluid diſcharged in the ſpark, paſſes through the metal wire; beſides, the violence of the electric ſparks generally corrodes or calcines part of the ſurfaces of thoſe bodies upon which they are taken, and even the rapid paſſage of the electric fluid through the air may burn ſome heterogeneous particles that float in it. In ſhort, all theſe cauſes may contribute to phlogiſticate the air; and in conſequence there is no neceſſity to ſuppoſe, that the electric fluid either is, or contains phlogiſton. Indeed, Dr. PRIESTLEY's experiment with the crooked tube, in which the electric ſparks are tranſmitted directly from the ſurface of the fluid in one leg to that of the fluid in the other, ſeems to be more in favour of his ſuppoſition; yet the phlogiſtication of the air even in this caſe may be owing to the ſeparation of phlogiſton from combuſtible particles, which either exiſt in the air or in the liquor.

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* Exper. and Obſerv. vol. i. part ii. ſect. 2.

† Ibid. vol. iv. ſect. 27. No. 6.

Mr. FONTANA, towards the latter end of the year 1779, made the following experiments, which ſeem to ſhew very clearly, that the phlogiſtication of common air by the electric ſparks is to be attributed to the diſcharge of phlogiſton from the wire or cement, rather than to the electric fluid itſelf. Mr. FONTANA made uſe of the inſtrument which we have already deſcribed in the preceding part of this work, which differed from that of Dr. PRIESTLEY principally in this, viz. that the wires were not faſtened by cement, but were fitted, by grinding, into two holes made on the ſides of a ſtrong glaſs tube. Mr. FONTANA uſed wires of different metals, and obſerved, that when the electric ſparks were taken between wires of impure metals, as iron and braſs, the phlogiſtication was eaſily effected, and in a conſiderable degree; but when wires of very pure ſilver were uſed, whoſe length was about 9 or 10 inches, the phlogiſtication of the air was effected in a ſmall degree, and after conſiderable time, as after taking ſparks for about half an hour.

Dr. WHITE, in the lxviiith vol. of the Phil. Tranſ. obſerves, that pure odours, as the odour of camphor, of muſk, and eſpecially volatile alkali; or the odours of vegetables, when extracted by art, and ſeparated from the putreſcent parts of the vegetables; have either very little or no power at all of contaminating common air, viz. of rendering it leſs diminiſhable by nitrous air. "Hence, except in particular "conſtitutions, or in caſes where their ſtimulus may be hurt- "ful, they may be ſafely uſed as agreeable odours, and to "obviate the ſmell in ſick rooms, &c."

The mixture of ſome permanently elaſtic fluids does alſo injure common air; but the particulars concerning thoſe effects will be conſidered when we treat of thoſe particular elaſtic fluids. It is only neceſſary to mention in this chapter, that the effect of nitrous gas upon common air is a real phlogiſtication; for the air, after that diminution, is unfit to aſſiſt reſpiration, combuſtion, &c.; in ſhort, it is in that ſtate in which it is called *phlogiſticated.*

The effects of nitre on air, as obſerved by Dr. Priestley, are worth particular notice, eſpecially becauſe they ſeem to throw great light upon the ſubject of the nature and properties of that ſingular ſalt, which has eluded the reſearches of many anxious philoſophers.—Dr. Priestley expoſed freſh-melted nitre to air, “ And I find,” *ſays he*, “ that common “ air, expoſed to nitre in theſe circumſtances, is a little injured, “ but with ſuch circumſtances attending the *proof* of it, as I “ had never obſerved before, and which I cannot well “ account for. The facts were as follow:

“ I melted about an ounce of ſalt-petre in a crucible, till “ all the air ſeemed to be expelled from it, and immediately “ placed it under a receiver ſtanding in water, where it pre-“ ſently became ſolid. The next morning I examined the air “ in which it had ſtood, and found it to be not ſo good as “ common air. It was diminiſhed about $\frac{1}{20}$ leſs than an “ equal quantity of common air, which I tried at the ſame “ time, and with the ſame nitrous air. I repeated the experi-“ ment ſeveral times, with the ſame reſult.

“ It was remarkable, however, that after theſe mixtures

" had remained a day and a night, they approached nearer " to an equality. This alſo I obſerved more than once, " and am much ſurprized at the fact. It ſhould ſeem, that " the air to which this nitre had been expoſed was not " abſolutely ſo much injured as the firſt mixture of nitrous " air with it would ſhew; but that its conſtitution was ſo " much altered, that it required more time for the phlogiſton " diſcharged from the nitrous air to act upon it.

" Afterwards I melted ſome ſalt-petre in a glaſs phial; and, " the veſſel being broken by the expanſion of the nitre in " cooling, I expoſed the nitre to a quantity of air confined " by water, ſo that the common air had acceſs to it on all " ſides; whereas, in the former experiment, it had been con- " tiguous to it at its ſurface only. After about a week, I " examined this air, and immediately after, by the trial " with nitrous air, found it to be conſiderably worſe than " common air; two meaſures of it, and one of nitrous air, " occupying the ſpace of two meaſures only; whereas the " mixture of common air, made at the ſame time, and with " part of the ſame quantity of nitrous air, was diminiſhed " as much as uſual. I did not carry this experiment any " farther, as I did with another quantity of common air, " which had likewiſe been expoſed about a week to melted " ſalt-petre in the ſame circumſtances.

" Two meaſures of this air, and one of nitrous, at firſt " occupied the ſpace of little more than two meaſures; but " it kept continually approaching to the degree of diminu-

“ tion of a mixture of common air, made at the ſame time, “ till after four days the difference between them was very “ ſmall *.”

It has been already obſerved, that air diſſolves and combines with water, and that probably a quantity of water is always combined with common air, which we have no means, at preſent, to ſeparate from it; we muſt now remark, that as water is abſorbed by air, ſo, on the other hand, a quantity of common air is alſo abſorbed by water. There is therefore a mutual attraction between thoſe two ſubſtances. If a glaſs full of water is put under the receiver of an air-pump, and the air is exhauſted from it, the water will bubble, and be agitated as it were actually boiling over a fire: which is owing to the air; which, when the preſſure of the atmoſphere is removed, re-aſſumes its elaſticity, and eſcapes out of the water: accordingly, when all the air that can by this means be ſeparated from water has been exhauſted, the apparent boiling ceaſes, notwithſtanding that the pump is ſtill kept in action. Boiling is another way to free water of air; thus, if a veſſel full of water is put upon the fire, and a glaſs receiver is filled with and inverted in that water, as the water begins to boil, a quantity of permanently elaſtic fluid, ſeparated from it, will be ſeen to occupy the upper part of the veſſel; which elaſtic fluid, if removed into another veſſel before it be imbibed again by the water in its cooling, will be found to

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* Exper. and Obſer. vol. ii. ſect. 9.

be permanently elaſtic, and conſequently it is not vapour. If a ſmall quantity of air be admitted into an inverted receiver full of water, out of which any contained elaſtic fluid has been extracted by boiling, or by the air-pump, that ſmall quantity of air will be intirely abſorbed by the water.—This abſorbtion is promoted by agitation. As the quantity of common air which can be imbibed by boiled water is eſtimated to be about one fortieth of the bulk of the water, the quantity of air admitted into the receiver, in the abovementioned experiment, muſt not be greater than about the fortieth part of the water contained in the receiver.

The bulk of the water is very little increaſed by the abſorbtion of air; which ſhews that the air's elaſticity muſt be in part deſtroyed, or that the ſubtile particles of that element are admitted into the interſtices exiſting between the particles of water.

Water abſorbs various quantities of the different permanently elaſtic fluids; thus it abſorbs a great quantity of fixed air or calcareous gas; it abſorbs an immenſe quantity of the alkaline or acid elaſtic fluids, and that without having been previouſly boiled, or deprived of air by means of the air-pump. The waters of various wells, mines, lakes, &c. called mineral waters, and alſo the waters of rivers, are naturally found impregnated with different proportions of various permanently elaſtic fluids. But theſe will be examined in the ſequel.

The air which is imbibed by diſtilled and boiled water, is not exactly the air of the atmoſphere in its uſual ſtate: but it ſeems that the water abſorbs the pureſt part of it, and leaves the worſt; for if a greater quantity of common air, than can be intirely abſorbed by a given quantity of boiled water, is expoſed to it, part of that air will be found to be abſorbed by the water, and the remainder will appear to be conſiderably phlogiſticated [*].—That this phlogiſton cannot wholly come from the water, ſeems evident from this, viz. that if, when the boiled water has abſorbed as much air as it can, more new common air be added to it, this will not be at all phlogiſticated, or at leaſt in an exceedingly ſmall degree, and after a very long time. But Mr. SCHEELE's ingenious experiments put this matter out of doubt; for he not only obſerved that the remaining quantity of air, after that boiled water had abſorbed a part of it, was ſo far injured as not to admit a candle to burn in it; but, boiling the water again, and thus extracting the air it had imbibed, found that this air was much purer than common air, ſo that a candle burned brighter in it than in common air [†].

From theſe obſervations it might perhaps be expected, that water in general, by boiling, ſhould yield air purer than common air; for having been expoſed to the atmoſphere, it muſt have imbibed the pureſt part of it, or the unphlogiſticated, in preference to the phlogiſticated part of it. But it muſt be conſidered, that the waters of rivers, wells, &c. are not expoſed to the open air only, but are mixed with various other ſubſtances, as earthy, metallic, and ſaline particles, vegetable or animal ſubſtances, and the like; which being diſſolved, putrefied, corroded, &c. produce various ſorts of elaſtic fluids, which are abſorbed by the waters, and thence, when they are boiled, yield various ſorts of permanently elaſtic fluids different from common air.

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[*] Dr. PRIESTLEY, having expoſed a quantity of common air to boiled water, found that it was diminiſhed of four ſevenths, and the remainder extinguiſhed flame. Exper. and Obſer. vol. i. p. 158.

[†] Exper. on Air and Fire, p. 164.

Mr. FONTANA made ſeveral experiments at Paris, in the year 1777, to aſcertain the quality of the elaſtic fluids ſeparated from various waters; the reſult of which is the following *.

The water of a well being boiled in a tin veſſel, which had a long neck or tube bent in two directions, like the glaſs tubes repreſented at I, in fig. 9, of plate II, yielded an elaſtic fluid, which ſeemed to be moſtly fixed air, mixed with a very ſmall quantity of phlogiſticated air; for it cryſtallized with oil of tartar, it turned the tincture of turnſole red, it precipitated the lime in lime-water, and it was abſorbed by water, to which it communicated an acidulous taſte; and the remainder, which was not abſorbed by water, nor precipitated the lime in lime-water, extinguiſhed flame.

The water of the river Seine, filtered through ſand, as it is drank at Paris, and treated in the ſame manner, yielded an

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* Phil. Tranſ. vol. lxix. p. 432, and following.

elaſtic fluid, which conſiſted principally of air purer than common air, with a ſmall quantity of fixed air. The air yielded by this water, when boiled in glaſs veſſels with doubly incurvated tubes, was ſtill purer than when boiled in the tin veſſel; ſo that it ſuffered a much greater diminution by nitrous air, it aſſiſted flame much better, and, in ſhort, it was purer than common air. The air obtained from this water was about the twenty-eighth part of its bulk.

The water d'Arqueil, which, at Paris, is conſidered as very pure, being boiled in the above-mentioned tin veſſel, gave an elaſtic fluid, which was partly fixed air and partly air that was not only better than common air, but even better than the air extracted from the water of the Seine. When this kind of water was boiled in glaſs veſſels, it yielded an elaſtic fluid ſtill purer. Mr. FONTANA extracted alſo the air from diſtilled water, and found it to be better than common air, and even better than the air obtained from the water of the Seine and of Arqueil. It was not ſenſibly diminiſhed in water, and in ſhort it was very good dephlogiſticated air. The quantity of air extracted from the water of the river Seine, is to that extracted from diſtilled water, as 32 to 13 nearly; but, as the elaſtic fluid extracted from the water of the Seine is half fixed air, Mr. FONTANA concludes, that the quantity of reſpirable air produced by either kind of water is nearly the ſame; only they differ a little in degree of purity. Mr. FONTANA, with his numerous experiments, obſerves that water, in general, abſorbs about twice as much of dephlogiſticated air, when expoſed to it, than of common air; or that, in general, water abſorbs a greater quantity of thoſe kinds of air which contain a leſs quantity of phlogiſton. He found that the water of the Seine, after being boiled for a long time, abſorbs about one fourteenth of its own bulk of dephlogiſticated air, whereas, in the ſame length of time, it does not abſorb more than one twenty-eighth of common air.

From theſe obſervations we ſee that common air may be partly changed into dephlogiſticated air; for ſuppoſe that a quantity of common air is expoſed to water recently boiled, the water will imbibe part of it; and if then that water be boiled in a glaſs veſſel, furniſhed with a bent tube, which, paſſing through the water of a tub, goes under an inverted receiver, the air obtained from that water will be found to be dephlogiſticated air.

Mr. FONTANA, in order to aſcertain whether or no the vapours of boiling water injured common air, introduced a quantity of common air, the goodneſs of which he had previouſly aſcertained by the taſte of nitrous air, then cauſed the ſteam of boiling water to paſs through it; which ſometimes rarefied the air ſo much as to make it occupy above five times the ſpace it did when cold; yet, after ſome time, the operation being intermitted, the air was found to be not at all altered by the ſteam *.

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* Phil. Tranſ. vol. lxix. p. 442.

It is clear that the air into which the ſteam of boiling water has been thrown, as ſoon as it cools, depoſits the ſteam, or rarefied water, which is an elaſtic fluid condenſible by cold; but whilſt the ſteam is in it, the air is pernicious to animals; though perhaps, if it were poſſible to be examined by the taſte of nitrous air, it would not appear to be unwholeſome. Not only the vapour of water, but the vapours and fumes of various other ſubſtances, when in conſiderable quantity, render the air unfit for reſpiration. MUSCHEMBROEK obſerved, that the vapour of pure water, introduced into a quantity of air, threw a bird into great anxiety; that the vapour of vinegar had the ſame effect; that the vapour of ſpirit of wine killed a bird; and that alſo the vapours of oil of turpentine, of oil of olives, and of ſpirit of ſalt-ammoniac, were fatal to animal life †.

In order to preſerve as much perſpicuity as this intricate ſubject will ſeem to admit of, the reader is requeſted to remark, that hitherto we have taken notice of the abſorbtion of air by water, (which abſorbtion is effected by mere expoſure) and of the change that the air undergoes in that abſorbtion; but now we ſhall conſider the phenomena produced by the agitation of air in water.

Air, by being kept in contact with common water, does not become phlogiſticated, at leaſt it has not been obſerved to become ſo after about one year ſtanding. The water, however, muſt be ſuppoſed to be not putrid, or impregnated with ſubſtances that are known to contaminate common air. But by agitation in water, good air is depraved, and phlogiſticated air is mended. To be more particular:—If a quantity of common air, in its natural ſtate, be agitated in water, even the pureſt that can be got, after ſome minutes the air will be found to be diminiſhed in bulk, and ſo far depraved as to extinguiſh the flame of a candle, though it is ſtill fit for reſpiration. By the taſte of nitrous air, it will be found to be leſs capable of diminution than it was before; and, in ſhort, it ſhews manifeſt ſigns of having acquired phlogiſton from the water *. On the contrary, if air diminiſhed by any phlogiſtic

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† Muſchemb. Introd. ad Philoſ. Nat. ſect. 2049.—In the third vol. of the Commentaria Bonon. it is mentioned, that the ſmell of camphor and of muſk was fatal to animals; and we might alſo add the ſmell and effluvia of many other things.—The vapour of new-plaſtered walls has been alſo found to be noxious.

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* This phlogiſtication of the air by agitation in water is not always accompanied with an equal degree of diminution; nor is it reaſonable to expect it, ſince it clearly depends upon the various nature of the water. "I agitated," *ſays Dr.* PRIESTLEY, "a quantity of common air in boiled water, and when I "had reduced it from eleven ounce meaſures to ſeven, I found that it extin-"guiſhed a candle, but a mouſe lived in it very well. At another time a candle "barely went out when the air was diminiſhed one third; and at other times I "have found this effect take place at other very different degrees of diminution. "This difference I attribute to the differences in the ſtate of the water with "reſpect to the air contained in it; for ſometimes it had ſtood longer than at "other times before I made uſe of it. I alſo uſed diſtilled water, rain-water, "and water out of which the air had been pumped, promiſcuouſly with rain-"water. I even doubt not but that, in a certain ſtate of the water, there might "be no ſenſible difference in the bulk of the agitated air, and yet at the end of "the proceſs it would extinguiſh a candle, air being ſupplied from the water, in "the

phlogiſtic proceſs, as reſpiration, putrefaction, &c. ſo as to be quite unfit for reſpiration and combuſtion, (in which ſtate it may be called thoroughly phlogiſticated air) be agitated in water for ſome minutes, afterwards it will be found to be ſo far mended as to be fit for reſpiration, and it efferveſces with or is diminiſhed by nitrous air, though it ſtill extinguiſhes flame; it is clear, therefore, that in this caſe the water has abſorbed part of the phlogiſton of the air. The mere contact of water, without agitation, has no effect upon contaminated air.

From thoſe obſervations we may deduce the following law, viz. that water and air have both an affinity with phlogiſton; that when air contains ſo much of that principle as that it will juſt extinguiſh flame, water, when

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" the place of that part of the common air which had been abſorbed."—Exper. and Obſer. vol. i. part i. ſect. 10.—And before that, in ſect. the 4th, he obſerves, that " If the water be freſh pump-water, there will always be an increaſe of the " air by agitation, the air contained in the water being ſet looſe, and joining that " which is in the jar. In this caſe, alſo, the air has never failed to be reſtored; " but then it might be ſuſpected that the melioration was produced by the " addition of ſome more wholeſome ingredient."

Mr. FONTANA, in the lxixth vol. of the Phil. Tranſ. p. 443, mentions to have found that common air, when ſhaken in water, is firſt increaſed in bulk; which increaſe becomes manifeſt after a few minutes agitation. This augmentation he ſays to have ſometimes brought to be one twelfth of the bulk of the air, and even more; though he confeſſes to have met with many irregularities in his experiments. After that this increaſe was arrived to a certain degree, a longer agitation cauſed then the air to be diminiſhed gradually, and at the ſame time to become leſs good. But Mr. FONTANA does not mention the quality of the water he uſed.

agitated in it, has no power to abſorb any of the phlogiſton from it; but when air contains more than that quantity of phlogiſton, then the water can ſeparate ſo much of it from that air, as to bring it to the ſtate in which it will juſt extinguiſh flame.—Thoſe facts alſo ſhew, that ſome phlogiſton is contained even in the water reckoned the pureſt.

In ſome caſes it may happen, that in the act of agitating air in water, ſome phlogiſton is ſeparated from the veſſels employed, in caſe theſe be not of glaſs; but an obſerver of theſe properties of natural bodies can hardly be ſuppoſed to be ſo ignorant as to make ſuch miſtakes.

Agitation of air in ſalt-water, and in water in which ſalt-petre had been diſſolved, Dr. PRIESTLEY obſerved, was attended with phenomena, upon the whole, like to when pure water is uſed *.

It is well known that water freſh diſtilled acquires an unpleaſant flavour, which it loſes by expoſure to the open air. This flavour Dr. PRIESTLEY obſerved to be owing to phlogiſton; for having confined ſome water, which had been diſtilled in glaſs veſſels, in a phial containing ſome air beſides, he found that, a month after, the air contained in the phial was conſiderably phlogiſticated. It is remarkable, that the water ſhould acquire phlogiſton by mere diſtillation; that is, by rarefaction and condenſation. It ſeems as if the phlogiſton was forced through the pores of the glaſs

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* Exper. and Obſer. vol. iii. ſect. 8. N. 2.

veſſel by the heat; but, as Dr. PRIESTLEY obſerves, it may be that water contains phlogiſton, and that evaporation changes the *mode of its combination*, and renders it more eaſy to be imparted to the air *.

The phlogiſtic matter which water abſorbs from the air, or otherwiſe, is reaſonably ſuppoſed to be imbibed by plants, and alſo by other ſubſtances under water; ſince it has often been obſerved, that the water of reſervoirs is preſerved ſweet as long as plants are growing on the ſides and bottom of the reſervoir, and as long as a ſlimy, foul ſubſtance exiſts in them; but that if they are cleaned, the water ſoon loſes its uſual ſweetneſs. This fact is well known in various places where reſervoirs are uſed, and eſpecially in ſome country places in the kingdom of Naples, where reſervoirs of water are very common. If the country people there are aſked the reaſon why they leave their reſervoirs ſometimes almoſt ſtopped up by the plants that grow in them, they commonly anſwer, that thoſe plants keep the water ſweet. Dr. PRIESTLEY mentions a fact, which ſeems to corroborate the above-mentioned ſuppoſition †.

When noxious air is required to be mended by agitation in water, the veſſel which contains the air ſhould be agitated in a trough of water, in which the water may communicate with the open air; for ſometimes the water ſerves as a vehicle for the putrid and phlogiſtic matter, from the noxious air within the receiver to the atmoſphere, as is ſhewn by the diſagreeable ſmell often perceived by the operator in this proceſs. When the noxious air is contained in a cloſed phial, wherein there is ſome water alſo, the air is either not at all, or very little, reſtored by agitation; becauſe, in this caſe, it can part with that quantity of phlogiſtic matter only which the ſmall quantity of confined water can abſorb.

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* Exper. and Obſer. vol. iv. p. 295.

† Ibid. vol. ii. ſect. 10.

I ſhall here juſt mention, that Dr. PRIESTLEY has diſcovered, that pump-water, kept in glaſs jars, and expoſed to the rays of the ſun, yields a conſiderable quantity of dephlogiſticated air.—The particulars relating this diſcovery will be examined in the chapter on dephlogiſticated air.

After all theſe obſervations, relating to the diminution of common air by various proceſſes, it is proper to remind the reader of ſome general phenomena concerning it.—Air, whenever expoſed to any ſubſtance which actually diſcharges the inflammable principle, becomes leſs fit for reſpiration, combuſtion, and other proceſſes for which it is neceſſary; and as the principle, which is ſeparated from thoſe bodies which contaminate common air, in many inſtances, is evidently the inflammable principle, the air is reaſonably ſuppoſed to become bad in conſequence of its union with that principle; it is therefore ſaid to be *phlogiſticated*: in which ſtate it is more or leſs unfit for other phlogiſtic proceſſes, in proportion as it has acquired a greater or leſs quantity of phlogiſton. This phlogiſtication is always attended with a diminution of the bulk of the air, which generally amounts to one fourth of the whole quantity, excepting when any elaſtic fluid is generated by the ſubſtances employed, in which caſe the diminution of the common air cannot be properly obſerved. The phlogiſtication of the air is limited; ſo that air that has been compleatly phlogiſticated is unfit to aſſiſt any other phlogiſtic proceſs, and is incapable of being diminiſhed farther.

It is now neceſſary to expand our views in reſpect to this ſubject, and to examine the ſtate of the atmoſphere in various parts and on various occaſions; conſidering the changes to which the atmoſpheric air is ſubject by various proceſſes naturally carried on upon the earth, and inveſtigating the various methods, which nature may employ in order to preſerve the atmoſpheric fluid in a proper degree of fitneſs for thoſe natural proceſſes for which it is abſolutely neceſſary. We ſhall here alſo examine the action of air upon plants, and the effects produced by the latter upon the former; which ſubject, although much elucidated of late, is yet involved in many obſcurities and uncertainties.

The firſt conſideration that naturally occurs is, that the whole maſs of atmoſpherical fluid, which ſurrounds the planet we inhabit, being continually contaminated by the reſpiration of many myriads of animals, by the burning of a great many artificial and natural fires, by the putrefaction and diſſolution of an infinite number of ſubſtances, and by many other phlogiſtic proceſſes, muſt gradually become more and more infected, till it be rendered abſolutely unfit for the purpoſes for which it is deſtined, except nature has provided ſome means to purify it, in proportion as it is contaminated, ſo as to keep it in a proper ſtate of ſalubrity, without growing continually worſe. That nature has provided ſuch correcting means, as we may call them, is hardly to be doubted, reaſoning from analogy; but the experimental inveſtigations of ſeveral excellent philoſophers of our time, clearly ſhew various natural proceſſes which muſt continually purify the air, and thus muſt counterbalance the effects of thoſe cauſes which tend to contaminate it.—We ſhall begin our examination of this intereſting point from what happens nearer to us.

The reſpiration of animals having been clearly ſhewn, in the preceding pages, to phlogiſticate common air, and, in proportion to the degree of that phlogiſtication, to render it leſs fit for animal reſpiration, combuſtion, &c. it naturally follows, that the air of thoſe houſes wherein many people live together, can never be ſo pure, and ſo fit for reſpiration, as the common open air. But, beſides this philoſophical conſideration, daily experience ſhews, that the air of thoſe places is not only leſs good than the open country air, but ſometimes it becomes ſo very offenſive, that contagious diſeaſes of a very dangerous nature are originated from it. In hoſpitals, priſons, workhouſes, large manufactories, veſſels containing many ſeamen, armies encamped in ſmall tracts of ground, and, in ſhort, in all thoſe circumſtances in which a great number of people are obliged to live in one houſe, or in a ſmall ſpace, we clearly ſee the diſagreeable effects of air tainted with animal reſpiration, and by all the other phlogiſtic proceſſes which muſt be neceſſarily carried on in thoſe places, as fires, putrefaction, the accumulation of excrements, and many others. The air tainted with thoſe noxious emanations is often offenſive to the noſtrils; but ſometimes it has not the leaſt perceivable ſmell, though it is ſo much vitiated, that it occaſions the moſt alarming diſeaſes in thoſe unfortunate perſons who are obliged to breathe it.

The ſame thing may be ſaid of air vitiated by other cauſes beſides the reſpiration of animals; thus the air is rendered offenſive by ſtagnating water, eſpecially in hot climates; in which many ſubſtances being putrified, a vaſt quantity of phlogiſtic matter, and putrid effluvia, are diſcharged into the adjacent air. Many places in the Eaſt-Indies, in America, and in Italy, furniſh numerous inſtances of this obſervation. Indeed, ſome of thoſe places are ſo dangerous, that ſometimes perſons who viſit them, in the hot ſeaſon, even for a few hours, are ſoon ſeized with a putrid fever of a very dangerous and obſtinate nature.

In towns, eſpecially large ones, all the cauſes which contaminate the air concur together; there the reſpiration of animals, the putrefaction of dead bodies, the combuſtion of large and numerous fires, the ſtagnation of waters, the proceſſes neceſſary for various articles of trade, and an infinite number of other cauſes, continually render the air impure, and impregnate it with noxious effluvia; hence large towns are often ſubject to epidemical diſeaſes, eſpecially in hot climates, and where the magiſtrate does not ſcrupulouſly invigilate on the cleanlineſs of the ſtreets and houſes of the inhabitants. There are, indeed, ſeveral of thoſe cauſes, which, in large towns, are unavoidable; but there are ſtill many, and thoſe very conſiderable, which might be eaſily removed; ſuch is the burial of the dead, which, conſiſtently with decorum and religion, might be performed in proper appointed places that lie far from the habitations, rather than between the circle of a town, and in thoſe places in which the air is leaſt ventilated. The carrying on of certain manufactures, and the erecting ſome public buildings, might alſo be baniſhed the walls of towns; or, at leaſt, they might, when it is practicable, be confined to particular eminent and ventilated places.

I need not mention any particular inſtances, nor fill my work with accounts of the diſeaſes which are communicated by the infection of the air, and to which priſoners, ſailors, ſoldiers, and other people who are often obliged to be crouded in a ſmall ſpace, are ſubject; ſince almoſt every phyſical book takes particular notice of them, and there are many excellent books written expreſsly on the ſubject, by very able and learned phyſicians, eſpecially Sir John Pringle's *Obſervations on the diſeaſes of the army.* I ſhall only obſerve, in general, that as the air may become impregnated with particular odoriferous emanations, ſo alſo it may become impregnated with offenſive effluvia of a particular ſort, which being communicated

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communicated to the body of a man, or other animal, occaſion one particular ſpecies of diſorder. This remark is confirmed by the ſpreading of various epidemical diſeaſes amongſt many people, when the ſound perſons had no commerce with thoſe that were infected. In hiſtories we meet with frequent inſtances of epidemical and peſtilential diſeaſes being ſuddenly ſpread over vaſt tracts of land, and having almoſt intirely depopulated ſeveral countries; the origin of thoſe plagues having been generally and evidently owing to the putrefaction of great quantities of animal or vegetable ſubſtances. A quantity of corrupted fiſh once occaſioned a terrible epidemical fever at Venice. The ſame effect was produced at Delft, by the corruption of a great many cabbages and other vegetables. The Arabs, as is related by Mr. Ives, when they have a mind to be revenged of ſome injury done them by the Turks at Baſſora, break down the banks of the river near that city, ſo as to let the water overflow a great tract of ground; and when the water is evaporated, the putrid mud, and other corrupted impurities, it leaves, corrupt the air to ſuch a degree, as to cauſe a moſt dreadful fever.

The general practice of phyſicians finds, that different conſtitutions are ſuited by different ſorts of air. There are ſome, who enjoy a tolerably healthy life in ſuch air as would be quite unfit for the generality of perſons. Uſe, and the gradual change, adapts the bodies of ſome men to thrive even in the worſt and moſt offenſive ſoils; yet thoſe people do never, or very ſeldom, enjoy a good ſtate of health, but generally ſhew by their countenances, and by their whole conſtitution, the bad ſtate of the air which they continually breathe. The ſudden change of the air is the moſt affecting. Plants, and ſome men like plants, who live in one and the ſame ſmall ſpot of ground, when they are tranſported into a different place, ſoon degenerate, and often periſh; whereas others, who are accuſtomed to a variety of climates, are by no means affected by thoſe changes, eſpecially when the tranſition is made by very ſmall and imperceptible degrees.

It is very remarkable, that ſeveral inſects live very well in very offenſive and putrid air. Indeed the ſwarms of inſects which live about putrid places, clearly ſhows the truth of this obſervation.

I ſhall now relate the principal obſervations, made by various ingenious philoſophers, upon the degree of purity of the air in various particular places.

Mr. Landriani, an ingenious Italian philoſopher, who undertook a journey through Italy purpoſely to obſerve the purity of the air in different places of that country, ſoon after his journey ſent a letter to Dr. Priestley, dated Nov. the 17th, 1776, wherein he thus expreſſes himſelf.——" Before " you receive this letter, I ſhall have ſent you my *eudiometer*, " together with a ſhort memoir, explaining the uſe of the " machine, in order to aſcertain with exactneſs the wholeſomeneſs of the air in any particular place. It is the ſame " inſtrument that I have made uſe of in my tour through

" Italy; in the courſe of which I have had the ſatisfaction " of convincing myſelf, that the air of all thoſe places which, " from the long experience of the inhabitants, has been re- " puted unwholeſome, is found to be ſo, to a very great degree " of exactneſs, by this inſtrument of mine; ſo that the " theory ſeems to correſpond very well to obſervation. In " the mountains near Piſa, I made trial of the air at different " heights, beginning on the plain, and proceeding to the " higheſt ſummits; and found a remarkable difference in " the ſtate of the air, every ſtratum being purer in propor- " tion as I aſcended. But making the ſame experiments on " mount Veſuvius, I found that, contrary to other moun- " tains, as I approached the lava, and the mouth of the " volcano (a new one having opened while I was at Naples) " the air appeared by my eudiometer to become ſenſibly " more vitiated. The air of the Pontine lakes, that of the " Sciroccho at Rome (ſo very unwholeſome) that of the " Campagna Romana, of the Grotta de Cane, of the Zolfa- " tara at Naples, of the baths of Nero at Baja, of the ſea- " coaſt of Tuſcany, were all examined by me, and found " to be in ſuch a ſtate as daily experience led me to " expect."

Notwithſtanding that Mr. LANDRIANI is deſerving great praiſe for his zealous and truly philoſophical undertaking, it is, however, natural to ſuſpect, that the ſucceſs of his experiments was, in a great meaſure, influenced by his expectations;

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ſince the exact agreement of his experiments with daily experience, and the pretended exactneſs, can hardly be ſuppoſed to be attainable with the inſtrument he uſed, (upon which particular remarks have been made in the preceding part of this work) or indeed with any ſort of eudiometer hitherto invented, as will appear by the following pages.

Mr. DE SAUSSURE, in his journey upon the Alps, having obſerved the air at the foot, on the middle, and at the ſummits of various mountains, with his peculiar method, of which we have taken notice before; makes the following general obſervations*.—That the air of the very low plains ſeems to be the leſs ſalubrious; that the air of very high mountains is neither very pure, nor, upon the whole, ſeems ſo fit for the lives of men, as that of a certain height above the level of the ſea, which he eſtimates to be about two or three hundred toiſes, that is, about 430 or 650 yards.

Dr.

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[*] " Ceux que j'ai obtenus en comparant ainſi l'air de la cime du Buet avec " celui de Chamouni, prouvent que l'air de cette vallée, mêlé avec l'air nitreux, " abſorbe un volume équivalent à 28 grains d'eau de plus que celui de la cime " de cette montagne. Trois autres expériences faites, l'une ſur le grand " S. BERNARD, l'autre ſur le le Piton, la troiſieme ſur le Voirons, ont toutes " donné des réſultats ſemblables, c'eſt-à-dire, que l'air de ces ſommites a paru " moins pur que celui des plaines ou des vallées, ſituées à leur pied. L'air qu'on " reſpire ſur le glacier du Taléfre eſt le ſeul, qui d'après ces épreuves, ait paru " meilleur que celui de la vallée de Chamouni; & cela vient vraiſemblablement " de ce que cet air eſt purifié par la quantité de vapeurs aqueuſes, parfaitment " pures, qu exhale l'étendue prodigieuſe de glaces & de neiges, au milieu deſ-

" quelles

Dr. White, in the lxviiith vol. of the Philoſ. Tranſ. giving an account of his experiment on air made at York, ſays that the atmoſpherical air was in a very bad ſtate, and indeed in the worſt he ever obſerved it, the 13th of September, 1777; when the barometer ſtood at 30,30; the thermometer ſtood at 69°; the weather being calm, clear, and the air dry and ſultry, no rain having fallen for above a fortnight. A ſlight ſhock of an earthquake was perceived that day.

The air of a bed-room at various times, viz. at night, and in the morning after ſleeping in it, has been examined by various perſons, and it has been generally found, that after ſleeping in it, the air is leſs pure than at any other time. The air of privies, even in calm weather, has not been found to be ſo much phlogiſticated as might have been expected, notwithſtanding its diſagreeable ſmell.

From this and other obſervations, it is thought that the exhalations of human excrements are very little if at all offenſive, except when they become putrid, or proceed from a diſeaſed body, in which caſe they infect the air very quickly.

Dr. Ingenhousz, ſoon after he left London, ſent an account

" quelles ce glacier eſt ſitué. Par ces mémes épreuves, l'air de Geneve a paru " égal à celui de Chamouni ; mais meilleur que celui des plaines du Piémont.

" Puis donc que de cinq montagnes ſur la çime deſquelles j'ai fait ces ex- " périences, quatre ont donné un air moins pur que celui des plaines ou des " vallées ſituées à leur pied ; & que la ſeule montagne qui ait donné un air " plus pur que celui de nos plaines, doit cet avantage à une poſition par- " tiuliere, il ſemble que l'on peut conclure de ces épreuves, qu'en général, " l'air à une certaine hauteur, perd un peu de ſa pureté."—p. 517.

of his experiments, made in the year 1779, upon the purity of the air at ſea, and other parts; which account was read at the Royal Society the 24th of April, 1780, and is inſerted in the lxxth vol. of the Philoſ. Tranſ. His firſt obſervations were made on board the veſſel in the mouth of the Thames, between Sheerneſs and Margate, where he found that the air was purer than any other ſort of common air he had met with before. He found that the ſea air taken farther from the land, viz. between the Engliſh coaſt and Oſtend, was not ſo pure as that tried before; yet this inferior purity ſeems not to take place always. The Doctor's general obſervations, deduced from his numerous experiments, are "that the air "at ſea, and cloſe to it, is in general purer, and fitter for "animal life, than the air on the land, though it ſeems to "be ſubject to ſome inconſiſtency in its degree of purity "with that of the land.

"That probably the air will be found, in general, much "purer far from the land than near the ſhore, the former "being never ſubject to be mixed with land air."

Dr. Ingenhousz, in the ſame paper, tranſcribes a journal of experiments, ſhewing the degree of purity of the air in various places, and under different circumſtances, which I ſhall inſert here in an abridged manner; thinking it of great uſe to other experimentators.

The method uſed by the Doctor, in thoſe experiments, was to introduce one meaſure of common air into the eudiometer-tube, and then one meaſure of nitrous air. The moment that theſe two ſorts of elaſtic fluids came into contact, he agitated the tube in the water-trough, and then meaſured the diminution, expreſſing it by hundredth parts of a meaſure; thus, when he ſays that ſuch air was found to be 130, it ſignifies, that after mixing one meaſure of it with one of nitrous air, the whole mixed and diminiſhed quantity was 130 hundredths of a meaſure, viz. one meaſure, more 30 hundredths of a meaſure.

" The different degrees of ſalubrity of the atmoſphere, as " I found it in general, in my country-houſe, at Southall " Green, ten miles from London, from June to September, " lay between 103 and 109.

" I was ſurprized, when, upon my return to town, to my " former lodgings, in Pall-Mall Court, I found the common " air purer, in general, in October, than I uſed to find it in " the middle of ſummer in the country; for on the 22d of " October, at nine o'clock in the morning, the weather being " fair and froſty, I found, that one meaſure of common air, " and one of nitrous air, occupied 100 ſub-diviſions in the " glaſs tube, or exactly one meaſure. That very day, at two " o'clock in the afternoon (it being then rainy weather) the " air was ſomewhat altered for the worſe. It gave 102.

" October the 23d, it being rainy weather, the air gave " 102.

" October the 24th, the weather being ſerene, the air, " at nine o'clock in the morning, gave 100.

" October the 25th, the ſky being cloudy, at eleven o'clock "in the morning, the air gave 102. At eleven o'clock at "night, from five different trials, it gave 105.

"October the 26th, the weather being very dark and "rainy, the air gave 105, as before."

The air at Oſtend was found, by the Doctor, to be generally very good, giving between 94 and 98.

At Bruges, the air, taken at ſeven o'clock at night, gave 105.

November the 8th, the air of Ghent, at three in the afternoon, gave 103.

November the 12th, the air of Bruſſels, at ſeven o'clock, P. M. gave 105½.

The next day, the air of the lower part of the ſame city gave 106, that of the higheſt appeared to be purer, as it gave 104; which agrees with the common popular obſervation. November the 14th, both the air of the higheſt, and that of the loweſt part of the city appeared to be of the ſame goodneſs, giving 103. The weather was froſty.

November the 22d, the air of Antwerp, in the evening, gave 109½; the weather being rainy, damp, and cold.

November the 23d, the air of Breda gave 106. The next day, about eleven o'clock, the air gave 102; the weather being fair, cold, and inclining to froſt. At ſeven o'clock it gave 103. Next day, being the 25th, the air gave 104; the weather being cold and rainy. The 26th it gave 103; the weather being very rainy, cold, and ſtormy.

November the 27th, the air at the Moordyke, cloſe to the water, gave 101½ the weather being fair and cold, but not froſty. This ſpot is reckoned very healthy.

November the 28th, the air of Rotterdam gave 103; the weather being rainy and cold.

November the 29th, the air of Delpht gave 103; the weather being ſtormy and rainy.

November the 30th, the air of the Hague gave 104; the weather being cold, and the wind northerly. The firſt of December the weather underwent a ſudden change; the wind becoming ſoutherly and ſtormy, and the atmoſphere becoming very hot. The day after, FAHRENHEIT's thermometer ſtood at 54°; and the common air, being repeatedly and accurately tried, gave 116; and that preſerved in a glaſs phial from the preceding day gave 117; and that gathered cloſe to the ſea gave 115.

December the 4th, the air of Amſterdam gave 103; the weather being rainy, windy, and cold. The day after, the weather continuing nearly the ſame, the air gave 102.

December the 10th, the air of Rotterdam gave 101; the weather being rainy.

December the 12th, being in the middle of the water between Dort and the Moordyke, the air gave 109; the weather being remarkably dark, rainy, and windy.

December the 13th, the air of Breda in the morning gave 109; the weather continuing as the day before. And in the afternoon the air gave 106½, the weather having cleared up.

December the 16th, the air of the lower part of the city of Antwerp gave 105; that of the higher part 104; the weather being rainy and temperate.

December the 17th, the air of Antwerp gave 107; the weather continuing nearly as in the preceding day.

December the 19th, the air of Bruſſels gave 109; the weather being rainy, windy, and rather warm.

December the 21ſt, the air of Bruſſels gave 106; the weather being dry and cold. The next day the air and weather continued the ſame.

December the 23d, the air of Mons gave 104; the weather being rainy and cold.

December the 24th, the air near Bouchain gave 104½; the weather being cloudy and cold.

December the 25th, the air of Peronne gave 102½; the weather being froſty.

December the 26th, the air of Cuvilli gave 103; the weather froſty.

December the 27th, the air of Senlis gave 102½; the weather froſty.

December the 29th, the air of Paris gave 103; the weather froſty.

1780. January the 8th, the air of Paris gave 100; the weather froſty.

January the 13th, the air of Paris gave 98; hard froſt.

Thus far with Dr. INGENHOUSZ's obſervations. His apparatus was a very portable one, made by Mr. MARTIN, which in reality is the eudiometer-tube and meaſure, as uſed by Mr. FONTANA, before he made his laſt-mentioned improvement. "The whole of this apparatus," *ſays Dr.* INGENHOUSZ, "was packed up in a box about ten inches "long, five broad, and three and a half high. The glaſs "tube or great meaſure, which was ſixteen inches long, and "divided in two ſeparate pieces, lay in a ſmall compaſs, "and could be put together by braſs ſcrews, adapted to the "divided extremities. Inſtead of a water-trough, ſuch as is "uſed commonly, I made uſe of a ſmall round wooden "tub, &c."

The reader may naturally remark, that with a ſmall apparatus, and with a common tub, wherein a proper ſhelf cannot be fixed, and alſo with the uſual inconveniences that are met with in travelling, thoſe experiments are not capable of ſuch accuracy as their nature, and the ſmall difference of their reſults, ſeems to require: yet Dr. INGENHOUSZ, by his great aſſiduity, was become very expert in the management of thoſe experiments; and, I may venture to aſſert, he has performed them with all the accuracy that the nature of the apparatus could admit of.

In the lxixth vol. of the Phil. Tranſ. Mr. FONTANA relates ſome experiments made by him upon the purity of common air, which are accompanied with very proper remarks. Thoſe experiments were made long before the above-mentioned obſervations of Dr. INGENHOUSZ; yet I have thought proper to take notice of them after thoſe of the Doctor, becauſe they contain ſeveral remarks applicable to the ſubject in general.—It ſeems proper to relate thoſe experiments and obſervations of that judicious and accurate philoſopher in his own words.

" I have," *ſays Mr.* FONTANA, " not the leaſt heſitation " in aſſerting, that the experiments made to aſcertain the " ſalubrity of the atmoſpherical air in various places, in different countries and ſituations, mentioned by ſeveral authors, are not to be depended upon ; becauſe the method " they uſed was far from being exact *, the elements or ingredients for the experiment were unknown and uncertain, " and the reſults very different from one another.

" When all the errors are corrected, it will be found, that " the difference between the air of one country and that of " another, at different times, is much leſs than what is commonly believed, and that the great differences found by " various obſervers are owing to the fallacious effects of uncertain methods. This I advance from experience; for I " was in the ſame error. I found very great differences " between the reſults of the experiments of this nature, which " ought to have been ſimilar; which diverſities I attributed " to myſelf rather than to the method I then uſed. At " Paris I examined the air of different places at the ſame " time, and eſpecially of thoſe ſituations where it was moſt " probable to meet with infected air, becauſe thoſe places

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* It is plain that Dr. INGENHOUSZ's method is not implied in this remark; ſince the Doctor's experiments were made long after, and the method uſed by him was properly that of Mr. FONTANA.

" abounded with putrid ſubſtances and impure exhalations; " but the differences I obſerved were very ſmall, and much " leſs than what could have been ſuſpected, for they hardly " arrived to one fiftieth of the air in the tube. Having " taken the air of the hill called Mount Valerian, at the " height of about 500 feet above the level of Paris, and " compared it with the air of Paris, taken at the ſame time, " and treated alike, I found the former to be hardly one " thirtieth better than the latter.

" In London I have obſerved almoſt the ſame. The air " of Iſlington and that of London ſuffered an equal diminu- " tion by the mixture of nitrous air; yet the air of Iſlington " is eſteemed to be much better. I have examined the air " of London, taken at different heights, (for inſtance, in the " ſtreet, at the ſecond floor, and at the top of the adjoining " houſes) and have found it to be of the ſame quality. " Having taken the air at the iron gallery of St. Paul's cu- " pola, at the height of 313 feet above the ground, and " likewiſe the air of the ſtone gallery, which is 202 feet " below the other; and having compared theſe two quantities " of air with that of the ſtreet adjoining, I found that there " was ſcarce any ſenſible difference between them, although " taken at ſuch different heights.

" In this experiment a circumſtance is to be conſidered, " which muſt have contributed to render the above-men- " tioned differences more ſenſible; this is, the agitation of " the air of the cupola, for there was felt a pretty briſk wind

" upon it, which I obſerved to be ſtronger and ſtronger the " higher I aſcended; whereas in the ſtreet, and indeed in " all the ſtreets I paſſed through, there was no ſenſible wind " to be felt. This experiment was made at four in the after- " noon, the weather being clear. The quickſilver in the " barometer, at that time, was 28,6 inches high, and " FARENHEIT's thermometer ſtood at 54°."

A few lines after, Mr. FONTANA proceeds thus:—" From " this we clearly ſee how little the experiments hitherto " publiſhed, about the differences of common air, are to be " depended upon. In general I find, that the air changes " from one time to another; ſo that the differences between " them are far greater than thoſe of the airs of different " countries, or different heights; for inſtance, I have found " that the air of London, in the months of September, " October, and November, 1778, when treated with the " nitrous air, gave II,I, 1,90, and II,II, 2,25*, which " is a mean reſult of many experiments, which differed " very little from each other. The 26th day of November " laſt I found the air, for the firſt time, much better, for " it gave II,I, 1,80, and II,II, 2,20; but, the 14th of " February, 1779, the air gave II,I, 1,69, and II,II, 2,21; " from whence it appears, that the air of this 14th of " February, was better than it had been for ſix months " before.

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[*] Mr. FONTANA's *formulæ* are here expreſſed according to our method of notation, mentioned in the VI. Chapter of the preceding Part.

"There can be no doubt of the accuracy of the experi-"ments, becauſe I compared the air taken at different times "with that which I had firſt uſed in the month of Septem-"ber, and which I had preſerved in dry glaſs bottles accu-"rately ſtopped."

This difference in the purity of the air at different times, Mr. FONTANA farther remarks, is much greater than the difference between the air of the different places obſerved by him; notwithſtanding this great change, as he obſerved, and as he was informed by various perſons, no particular change of health in the generality of people, or facility of breathing, was perceived.

Mr. FONTANA laſtly concludes with obſerving, that "Na-"ture is not ſo partial as we commonly believe. She has "not only given us an air almoſt equally good every where, "at every time, but has allowed us a certain latitude, or a "power of living and being in health in qualities of air "which differ to a certain degree. By this I do not mean "to deny the exiſtence of certain kinds of noxious air in ſome "particular places; but only ſay, that, in general, the air is "good every where, and that the ſmall differences are not "to be feared ſo much as ſome people would make us believe. "Nor do I mean to ſpeak here of thoſe vapours and other "bodies which are accidentally joined to the common air in "particular places, but do not change its nature and intrin-"ſical property. This ſtate of the air cannot be known by "the taſte of nitrous air, and thoſe vapours are to be con-

" ſidered in the ſame manner as we ſhould conſider ſo many " particles of arſenic ſwimming in the atmoſphere. In this " caſe it is the arſenic, and not the degenerated air, that " would kill the animals who ventured to breathe it."

We ſee, by the obſervations of this accurate philoſopher, that the air of different ſituations does not appear to be much different in purity; or rather, that the taſte of nitrous air is not ſufficient to diſcover the purity of the air in every circumſtance. This obſervation is farther confirmed by Dr. PRIESTLEY, who, in his fourth volume of Exper. and Obſer. frankly confeſſes, that, from his various experiments, the taſte of nitrous air appeared not to be a very accurate criterion of the wholeſomeneſs of common air. The Doctor having examined, by means of nitrous air, ſeveral ſpecimens of air ſent him from various places, eſpecially from manufacturing towns, and confined places, found very little difference between them and ſuch common air as is reckoned very good. However, as appears from the narration of his experiments, this difference, though trifling, ſeems conſtantly to ſhew that the good common air ſuffered the greater diminution. The air of hot-houſes, which generally affects the people with an oppreſſion or difficulty of reſpiration; alſo the air of a calico-printing-houſe, which was very offenſive; and a ſpecimen of intolerably ſtinking and nauſeous air taken in the hold of a veſſel, being examined by Dr. PRIESTLEY, were found to be diminiſhed by nitrous air very little leſs than the good air of Wiltſhire was, when treated in a ſimilar manner. The worſt ſpecimen of air which he examined, was that taken in a coal-pit in the neighbourhood of Briſtol. The air of dining-rooms, Dr. PRIESTLEY obſerves, to be ſoon and conſiderably vitiated by company ſitting in it, becauſe the victuals, the candles, and the reſpiration, do all contribute to contaminate it, eſpecially when the room is well cloſed, and its ſize is ſmall in proportion to the company, &c. " The extreme " offenſiveneſs," *ſays the Doctor*, " of the air in theſe cir- " cumſtances is not perceived by perſons who ſit in it from " the beginning; but it is immediately perceived by perſons " who ſtep out of the room, and return to it.

" Dining one time in a company of not more than eight or " ten perſons, in a large and very lofty room, and being " called out preſently after the cloth was removed, I was " much ſtruck with the offenſiveneſs of the air on my return; " and being willing to aſcertain the *degree* in which it was in- " jured, I took occaſion, on ſome pretence or other, to pour the " water from one full decanter into another, and putting in " the ſtopper, ſaw that nobody opened it till the company ſe- " parated. I then took the decanter into my laboratory, and " examined the air at my leiſure; when it appeared to be " much contaminated. For one meaſure of this air, and " one of nitrous air, occupied the ſpace of 1.31 meaſures; " when the ſame experiment being made with the air of a " well-ventilated room in the ſame houſe, the meaſures were " 1.43. At the ſame time I breathed a quantity of air till it " juſt extinguiſhed a candle, and found that the meaſures

" were 1.43. So that, had the air of the dining-room re-
" ceived a little more than twice as much more phlogiſtic
" matter, as it was charged with by the breathing of theſe
" eight or ten perſons, the effluvia of the victuals, &c. a
" candle would not have burned in the room. I would ad-
" viſe, therefore, that when ſuch large dining-rooms are built,
" proviſion be made for letting out the vitiated air at the top
" of them. For breathing ſuch contaminated air, ſo long a
" time as it is now the cuſtom to do, at and after dinner,
" muſt be very hurtful. Otherwiſe, if it were not incon-
" venient on other accounts, it would be better to have the
" dinner in one room, and the deſſert in another *.

In the ſame ſection Dr. PRIESTLEY relates his having examined by various ways the effect of the *ſenſible* or *inſenſible* perſpiration of his body on air; but he found that the air was not ſenſibly worſted, and ſometimes was rendered ſeemingly a little better by it. I have alſo done the ſame thing, in a manner rather different from thoſe of the Doctor, but my experiments were attended with the ſame reſult.

From all the above-mentioned obſervations on the purity of the air of different places, and the taſte of nitrous air, the following inferences ſeem to be naturally deducible.

I. The atmoſpherical air ſeems to be nearly the ſame, in reſpect to purity, in different places; at leaſt the differences of the diminutions effected by mixing nitrous air with the airs of various places are very ſmall; excepting the air of thoſe places in which a vaſt quantity of phlogiſtic matter is evidently imparted to the air, as is the caſe in the vicinity of putrid marſhes, and other ſuch-like places. This equability of the air's purity in different places, ſeems very natural, when we conſider that good and vitiated air are ſo quickly intermixed by the winds, and, in ſhort, by the continual and quick agitation of the atmoſphere.

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* Exper. and Oſerv. vol. iv. ſect. 27.

But, independent of philoſophical experiments, the air of different countries, and thoſe not very far from each other, differs in point of purity, or fitneſs for ſupporting animal life. The common practice of phyſicians, the ſickly conſtitution of the inhabitants of ſome countries, and the healthy nature of thoſe of others, do clearly evince the truth of this remark. The great point for philoſophers to inveſtigate is, whether the remarkable effects of the air on the conſtitutions of people is owing to that ſmall phlogiſtication of the air which is diſcoverable by the taſte of nitrous air, or to ſomething elſe.

II. The taſte of nitrous air is not generally a ſure method to diſtinguiſh the purity of common air; for ſometimes air, which appears to be very good by the taſte of nitrous air, is in reality very offenſive, and unſafe for animal reſpiration; though, on the other hand, it is certain, that air, which by the taſte of nitrous air appears to be bad, is always unfit for reſpiration, combuſtion, &c. The diminution ariſing from the mixture of nitrous with common air, being a phlogiſtic proceſs, ſhews only when the air contains a greater or leſs quantity of that element; but the air may be charged with other effluvia, and even phlogiſtic ones, though the phlogiſton may not be properly and intimately combined with the air; under which circumſtances the air may be quite unfit for reſpiration, yet its depravity is not diſtinguiſhable by means of nitrous air. The ſmell is far from being always accompanied with the depravity of the air; for ſometimes air which has a very diſagreeable ſmell is not offenſive, and, on the contrary, air which is noxious to the higheſt degree does not in the leaſt affect the ſenſe of ſmell.—Were the lives of ſmall animals of the ſame ſpecies, as of birds, or of mice, &c. ſimilarly affected by like and equal cauſes, to confine ſuch animals in equal quantities of different ſorts of air, and to note the times of their living in them till they become extinct, would be the ſureſt but cruel method of aſcertaining the degree of purity of the air.

III. The air of different ſeaſons, or of different times, has been found to be more varying in degree of purity than the air of different places at the ſame time. In the winter, when the weather is clear and froſty, the air has been generally found to be in the pureſt ſtate; probably, becauſe the corruption of ſo many ſubſtances is at that time retarded, and in great meaſure hindered, by the cold. Accordingly, in the ſummer, and eſpecially in the autumn, when a vaſt quantity of vegetable and animal ſubſtances lie upon the ground, and their diſſolution and putrefaction is haſtened by the heat, and alſo by the continual moiſture, when thoſe ſeaſons happen to be very rainy, the air is then leſs pure. But ſome ſudden changes in the air's degree of purity are often obſervable at unexpected times, eſpecially at the changing of certain winds.

The variations of the air's purity, and the concomitant phenomena, are highly intereſting to mankind in general; by the diſcoveries made principally in the preſent age, ſeveral methods are deduced by which this ſubject may be examined, and many uſeful obſervations have been actually made concerning it. But the eſſential part ſeems to be ſtill in the dark; it is therefore requiſite that philoſophical people, in various parts of the world, would make as many and as various experiments, concerning the purity of the air at different times, as they can conveniently contrive and perform, in order to inveſtigate the laws of thoſe changes; which ſubject is perhaps the moſt intereſting part of the ſtudy of elaſtic fluids.

We are now to examine the natural and artificial means of purifying contaminated air, and alſo the effects of plants upon that element.

That the air which has ſerved for reſpiration, and for combuſtion, during a certain time, is unfit to aſſiſt thoſe proceſſes any longer, has been known to philoſophers for many ages; but to attempt to purify contaminated air, and to render it again fit for reſpiration, combuſtion, &c. and eſpecially to inveſtigate the methods which nature uſes for this great reſtoration, has been the object of very late philoſophers. Upon the old ſuppoſition, that the particles of bodies of almoſt every kind, either by heat, diſſolution, or other means, aſſumed an elaſtic form, and became reſpirable air, it might be eaſily imagined that the air, which is continually contaminated by the innumerable phlogiſtic proceſſes, is abſorbed by water, vegetables, or other bodies, and that at the ſame time new air s continually generated, ſo as to preſerve the whole ſtock of atmoſpheric air always in a proper and uſeful degree of purity. But, ſince that ſuppoſition cannot be thought plauſible, in the preſent ſtate of knowledge relating to the ſubject of permanently elaſtic fluids, this explanation is not ſatisfactory.

Mr. BOYLE relates of one *Drebell*, who pretended to have found out a liquor, the effluvia of which could render contaminated air again good for reſpiration. The account is as follows:—" And, upon this ſuppoſition, *Cornelius Drebell* " is affirmed, by many credible perſons, to have contrived a " veſſel to be rowed under water; for *Drebell* conceived, " that it is not the whole body of the air, but a certain " ſpirituous part of it, that fits it for reſpiration; which be- " ing ſpent, the remaining groſſer body of the air is unable to " cheriſh the vital flame reſiding in the heart. So that, " beſides the mechanical contrivance of his boat, he had a " chymical liquor, which, by unſtopping the veſſel wherein " it was contained, the fumes of it would ſpeedily reſtore " to the air, fouled by reſpiration, ſuch a proportion of " vital parts, as would make it again fit for that office; and " having made it my buſineſs to learn this ſtrange liquor,

" his relations conſtantly affirmed, that *Drebell* would never " diſcloſe it, but to one perſon; who himſelf told me what it " was *."

The nature of this liquor was never publicly known, and probably it did never in reality exiſt; ſince it is now aſcertained, that the air's unfitneſs for reſpiration, &c. is owing, not to its having loſt a vital principle, but to its having imbibed a ſubſtance, to wit, phlogiſton, which cannot be eaſily ſeparated again from the air; eſpecially by the fumes of a liquor.

Perhaps the above-mentioned *Drebell* made the people believe that he had a liquor capable to reſtore the air, though, in reality, they lived in that confined air only becauſe its quantity was ſufficient to ſupport their lives for the ſhort time they remained in the veſſel in that ſubmarine navigation. Were it poſſible to be known the ſize of the veſſel, as well as the time of its remaining under water, and other particulars, we might eaſily and pretty nearly calculate, if the number of people employed could live in that confined quantity of air for the known length of time, without changing or altering the nature of the air. But this is not particularly related †.

Previous to the narration of thoſe methods and natural proceſſes which have been found to correct contaminated air, I think it proper to relate ſeveral unſucceſsful attempts of that nature, becauſe at firſt ſight they ſeem very plauſible, and may very likely induce ſeveral experimentators to try them, and thus to repeat the ſame fruitleſs experiments which other obſervers have in vain attempted before.

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* Boyle's Works, on the ſpring of the air, exper. 41.

† It is only ſaid, that this veſſel was made for King James I. and that it carried twelve rowers, beſides the paſſengers. It was tried in the river Thames. See the note (b) to Chap. I. Book I. of Dr. Derham's Phyſico-theology.

Dr. PRIESTLEY tried the following unſucceſsful methods:—He found that mere ſtanding, even for ſeveral months, in freſh or ſalt water, without agitation, is ſo far from meliorating air contaminated by reſpiration, that it is rendered rather more deadly by it.

The action of light, or of any other influence which may paſs through the pores of glaſs, was found ineffectual to correct this contaminated air, when it was kept in a thin phial in the open air for ſeveral months.

The Doctor tried to correct the phlogiſticated air by a great variety of thoſe effluvia, which continually exhale into the air, and which ariſe from thoſe ſubſtances that are wont to reſiſt putrefaction; but to no purpoſe.

The fumes of burning brimſtone *; and alſo the fumes of ſpirit of nitre, and of crude nitre which was heated by means of a burning-glaſs, were tried without any effect.

Heat, even a very ſtrong degree of it, was incapable to reſtore contaminated air.—As the manner of performing this experiment

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* This experiment was ſuggeſted to the Doctor, by the account publiſhed in the Memoirs of the Imperial Society, of a plague not affecting a particular village, in which there was a large ſulphur-work.

experiment is very well contrived, and may be of uſe for other trials, I ſhall add, in the note, Dr. PRIESTLEY's own words *.

Rarefaction and condenſation by inſtruments; and expoſure to a quantity of fine garden-mould, were alſo found by the Doctor to be incapable to meliorate air infected by animals breathing and periſhing in it.

Rarefaction and condenſation, by heat and artificial cold, are incapable to purify tainted air.

If air, infected by putrefaction, be agitated in water acidulated by vinegar, or by the mineral acids, it will not thereby be mended, at leaſt the effect is generally the ſame as if water only was uſed.

To mix tainted air with other ſorts of elaſtic fluids does neither correct it. Indeed there are ſome obſervations in Dr. PRIESTLEY's firſt volume of Experiments and Obſervations, which ſeem to ſhew that the addition of fixed air, in ſome circumſtances, meliorates infected air, but when they are duly examined, evidently ſhew that the melioration of air,

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* "In order to try the effect of *heat*, I put a quantity of air in which mice "had died, into a bladder, tied to the end of the ſtem of a tobacco-pipe, at the "other end of which was another bladder, out of which the air was carefully "preſſed. I then put the middle part of the ſtem into a chafing-diſh of hot coals, "ſtrongly urged with a pair of bellows; and preſſing the bladder alternately, I "made the air paſs ſeveral times through the heated part of the pipe. I have "alſo made this kind of air very hot, ſtanding in water before the fire. But "neither of theſe methods were of any uſe." Exper. and Obſer. vol. i. part i. ſect. 4.

in thoſe caſes, is owing to other cauſes, rather than to the mixture of fixed air. From this obſervation, however, we muſt except the mixing of the vitiated air with dephlogiſticated air; for, in that caſe, it is evident, that the compound muſt be purer than the bad air was by itſelf; and that more or leſs, in proportion to the quantities and qualities of the two elaſtic fluids employed.

Notwithſtanding that the various above-mentioned means have been found ineffectual in reſtoring vitiated air, it is, however, not improbable that nature may employ ſome of thoſe very ſame means to purify the atmoſphere. For inſtance, the rarefaction of the air in the more exalted regions of the atmoſphere, the influence of cold or heat, &c. may contribute to that end, when they act all together, and for a conſiderable time.

In purſuance to thoſe experiments of Dr. PRIESTLEY and others, I have myſelf often attempted to mend air infected with the effluvia of putrid meat, by keeping it in contact with the decoctions of thoſe ſubſtances which are reckoned powerful in reſtraining putrefaction; eſpecially the decoction, and alſo the ſimple infuſion of Peruvian Bark; ſometimes agitating the phials very violently, or keeping them ſtill for ſeveral days; but, in general, my experiments were attended with the very ſame reſult as if ſimple water had been uſed.

The only effectual method, at preſent known, of removing bad air from thoſe places in which it is unavoidably and abundantly produced, is ventilation, that is, a continual change of the air. This ventilation is ſometimes naturally effected by the nature of ſome buildings, or by the nice diſpoſition of walls, ſtreets, &c.; but in places which do not admit of ſuch proper diſpoſition, the ſame effect is produced by ventilators, which are a kind of large bellows, that, when put in action, draw in the outward air, and diſcharge it within thoſe places in which there is leſs natural ventilation. Thoſe ventilators, which have been contrived of various forms, and ſo as to go by wind or water, or a horſe, having been uſed in priſons, hoſpitals, the holds of ſhips, and other places, have been generally found very uſeful. In the conſtruction and diſpoſition of ventilators, care ſhould be taken to direct the ſtream of cold air, that proceeds from them, ſo as not to fall immediately upon the people.

It is evident that this ventilation cannot be called a method of meliorating bad air; for it does only change the bad air for that which is more pure.

Dr. HALES was perhaps the firſt who diſcovered a method of meliorating air infected by reſpiration; at leaſt, he found that he could breathe for a much longer time a quantity of air, which, in the courſe of reſpiration, was made to paſs through ſeveral folds of cloth dipped in vinegar, or in a ſolution of ſea ſalt, or particularly in oil of tartar, than the ſame quantity of common air when no ſuch filtration was uſed *. The preſent advanced ſtate of the ſubject readily

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* Stat. Eſſays, vol. i. p. 266.

offers an explanation of this phenomenon, ſince it is now well known, that, by the act of reſpiration, part of the common air is changed into fixed air, or at leaſt the fixed air is by ſome other means generated; and that the water of the ſolution of ſalt, the vinegar, and eſpecially the oil of tartar, through which the reſpired air was obliged to paſs, abſorb fixed air; ſo that the fixed air being abſorbed, in Dr. HALES's experiment, as ſoon as it was generated, the remaining air remained uſeful for reſpiration much longer than otherwiſe.

Thus if three animals of the ſame ſpecies, &c. be confined each in a glaſs receiver, containing a given and conſtant quantity of common air; but with this difference, that one of thoſe receivers be inverted in quickſilver, another be inverted in common water, and another in lime-water, and be alſo kept continually agitated—the reſult will be, that the animal of the firſt receiver will die firſt, then that of the ſecond, and laſtly that of the third receiver will periſh; becauſe the fixed air generated by the reſpiration of thoſe animals, and which fixed air is highly noxious, is not imbibed by the quickſilver, but is abſorbed in great meaſure by the water, and is much more readily, and in greater quantity, abſorbed by the lime-water, eſpecially when the veſſel is agitated.

Dr. PRIESTLEY ſuſpects that unwholeſome air may loſe ſome of its pernicious quality by mere ſtanding in a veſſel for a long time. "I have reaſon," *ſays he*, "to think that when "very unwholeſome air is conveyed to a great diſtance, "and much time elapſes before it is tried, it approaches, by "ſome means or other, to the ſtate of wholeſome air *." Perhaps this melioration of the air by mere ſtanding, may take place only when ſome of the offenſive or putrid effluvia mixed with it are of ſuch a nature as to be ſuſpended in the air, in conſequence of their particular ſpecific gravity, but not when they are truly combined with the aerial particles.

It has already been obſerved in the preceding pages, that agitation in water mends air tainted with reſpiration and putrefaction; and we may ſay in general, that it mends bad or phlogiſticated air, in whatſoever it may have been depraved. That the water, in this caſe, abſorbs from the air ſomething elſe beſides fixed air, is plain from various obſervations, but principally becauſe phlogiſticated air, that does not contain any fixed air, as the air phlogiſticated by the calcination of metals, is alſo conſiderably mended by agitation in water. It ſeems, therefore, plain, that water abſorbs the phlogiſton from phlogiſticated air, when agitated in it. That this may be one of the methods employed by nature for the purification of the atmoſphere in general, ſeems exceedingly probable, and analogous to ſome of its other great operations. Not only the continual agitation of the water of the ſea, rivers, lakes, &c. but alſo the rain and dew, may contribute to that great purpoſe.

The drops of rain from the place where they are formed,

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* Exper. and Obſer. vol. iv. p. 270.

till they fall upon the ground, muſt paſs through a vaſt quantity of air, and, by touching its particles, muſt certainly waſh and ſeparate from them many heterogeneous bodies which infect the atmoſphere. Independent of the above-mentioned philoſophical experiments, this aſſertion is confirmed by the common obſervation, of the rain-water being at ſome particular times, and eſpecially in certain countries, evidently impregnated with various ſaline, earthy, and other ſubſtances, which often give it a peculiar taſte and ſmell.

Dr. PRIESTLEY's unſucceſsful experiments concerning this ſubject, and his unwearied labour, were at laſt rewarded, by the diſcovery of a natural method of meliorating contaminated air. He found that air, which had been rendered perfectly noxious by animals breathing and dying in it, was ſo far reſtored by the vegetation of plants, that, after ſome days, an animal would live in it nearly as well and as long as in an equal quantity of common air.

This, like other great diſcoveries, was imperfect at firſt; for ſometimes the phenomena attending the experiments varied, when all the apparent neceſſary circumſtances were the ſame; ſo that, by the vegetation of the ſame ſpecies of plants, air, equally noxious, was not always purified alike. And the Doctor himſelf, with his uſual candour, ſeems, in ſome part of his publications, to doubt of the general truth of this law. But by farther obſervations, and eſpecially by the late experiments of Dr. INGENHOUSZ, this ſubject has been much elucidated.

“ When air,” *ſays Dr.* PRIESTLEY, “ has been freſhly and “ ſtrongly tainted with putrefaction, ſo as to ſmell through “ the water, ſprigs of mint have preſently died, upon being “ put into it, their leaves turning black; but if they do not “ die preſently, they thrive in a moſt ſurpriſing manner. “ In no other circumſtances have I ever ſeen vegetation “ ſo vigorous as in this kind of air, which is immediately “ fatal to animal life.

“ Though theſe plants have been crouded in jars filled “ with this air, every leaf has been full of life; freſh ſhoots “ have branched out in various directions, and have grown “ much faſter than other ſimilar plants, growing in the “ ſame expoſure in common air [*].”

The Doctor having rendered a quantity of air thoroughly noxious, by mice breathing and dying in it, divided it into two receivers, inverted in water; then he introduced a ſprig of mint into one of them, and kept the other unaltered. About eight or nine days after, he found, upon trial, that the air of the receiver in which the ſprig of mint had vegetated, was become again reſpirable; for a mouſe introduced in it lived very well, whereas it died the moment it was introduced into the air of the other glaſs jar. This experiment was made in the month of Auguſt 1771. The Doctor having repeated it ſeveral times, both in that and the following year, and with air tainted either by animals breathing and dying in it, or by the putrefaction of animal and vegetable ſubſtances, generally met with the ſame ſucceſs; but he remarks, that towards the end of the year, ſome experiments of this kind did not anſwer ſo well as in the hot ſeaſon.

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[*] Exper. and Obſer. vol. i. part i. ſect. 4.

The general inferences which may be deduced from thoſe experiments of Dr. PRIESTLEY are the following. I. The vegetation of plants is capable to purify air tainted by reſpiration, and by putrefaction of animal and vegetable ſubſtances. When the air is truly noxious, vegetation does not purify it to ſuch degree as that a candle will burn in it; but air infected by the burning of a candle will be mended by vegetation, ſo that a candle will burn in it again. II. This melioration of tainted air by vegetation is effected in a few days; a long time ſeems to render the reſult uncertain; for ſometimes Dr. PRIESTLEY found that tainted air was not only not mended, but rather rendered worſe, by plants vegetating long in it. Perhaps this effect may be owing to ſome leaves, or other parts of the plants, becoming dead or putrid. III. Laſtly, It ſeems probable that plants abſorb ſome of the phlogiſton, or putrid and other effluvia from the air, and that this imbibed phlogiſton is gradually incorporated with their ſubſtance, ſo as to be, in great meaſure, their aliment; it being well known that putrid matter affords proper nouriſhment for their roots; and it is likely that plants ſhould alſo imbibe phlogiſtic and putrid effluvia from the air, through the pores of their leaves, ſtocks, &c.

" Theſe proofs," *ſays Dr.* PRIESTLEY, " of a partial " reſtoration of air by plants in a ſtate of vegetation, though " in a confined and unnatural ſituation, cannot but render it " highly probable, that the injury which is continually done " to the atmoſphere by the reſpiration of ſuch a number of " animals, and the putrefaction of ſuch maſſes of both vegetable and animal matter, is, in part at leaſt, repaired by the " vegetable creation. And, notwithſtanding the prodigious " maſs of air that is corrupted daily by the above-mentioned " cauſes, yet, if we conſider the immenſe profuſion of vegetables upon the face of the earth, growing in places ſuited " to their nature, conſequently at full liberty to exert all " their powers, both inhaling and exhaling, it can hardly " be thought, but that it may be a ſufficient counterbalance to " it, and that the remedy is adequate to the evil *."

After the publication of thoſe experiments and obſervations concerning the above-mentioned power of plants, ſeveral perſons, among thoſe who endeavoured to repeat them, could not ſucceed; in conſeqence of which, Dr. PRIESTLEY reaſſumed this courſe of experiments in the ſpring and ſummer of 1778, and publiſhed an account of their reſult in his fourth volume of Experiments and Obſervations.

They furniſh the following general remarks.—Having tried the power of ſeveral ſorts of vegetables upon air infected by reſpiration, or by the burning of candles, he found that the air was generally rendered worſe by their vegetation, and the longer the plants were kept in the infected air, the more they phlogiſticated it; though in ſeveral caſes the air was undoubtedly meliorated, eſpecially by the ſhoots of ſtrawberries, and ſome other plants, which were introduced into the phials containing foul air, and inverted in water, which were placed near them, whilſt their roots continued in the earth, in the garden. Sometimes the infected air was ſo far mended by the vegetation of plants, that it was, in great meaſure, turned into dephlogiſticated air; ſo that, in general, the reſult of this ſecond courſe of experiments ſeemed to have been rather contradictory to that of the former, and conſequently not ſo favourable to the above-mentioned hypotheſis. "Upon "the whole," *ſays Dr.* PRIESTLEY, "I ſtill think it *probable* "that the vegetation of healthy plants, growing in ſituations "natural to them, has a ſalutary effect on the air in which "they grow. For one inſtance of the melioration of air in "theſe circumſtances, ſhould weigh againſt a hundred caſes in "which the air is made worſe by it, both on account of the "many diſadvantages under which all plants labour, in the "circumſtances in which theſe experiments muſt be made, "as well as the great attention and many precautions that "are requiſite in conducting ſuch a proceſs *."

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* Exper. and Obſerv. vol. i. part i. ſect. 4.

The ſmell of flowers, even the moſt delicate, Dr. PRIESTLEY obſerved, injures common air. A full-blown roſe having been put in a glaſs jar, containing about four ounce meaſures of common air, was found to infect the air ſo much, that, the day after, it was become quite unfit for reſpiration, and three days after it was rendered ſo bad that it ſuffered hardly any ſenſible diminution by nitrous air. Yet the roſe, when taken out of the receiver after thoſe three days, appeared to retain all its agreeable ſmell. This fact, however, has not been conſtantly obſerved by thoſe who have repeated ſuch experiments; for with ſome perſons the air was either very little or not at all phlogiſticated by flowers being confined in it. But thoſe experiments are ſubject to many variations and uncertainties.

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* Exper. and Obſer. vol. iv. p. 302.

In the courſe of the above-mentioned experiments on plants, Dr. PRIESTLEY diſcovered that the *willow-plant* (called by LINNÆUS *epilobium hirſutum)* had the remarkable property of abſorbing a conſiderable quantity of common air, and alſo of nitrous and of inflammable air*. The quantity of common air, which remained unabſorbed in the receiver, was found phlogiſticated; yet the diminution could not be intirely attributed to the phlogiſtication, becauſe that means will not diminiſh common air of more than one fourth at moſt; whereas the quantity of air expoſed to the willow-plant was ſometimes almoſt intirely abſorbed. The remainder of inflammable air, (when this elaſtic fluid was uſed) after that the willow had abſorbed part of it, was ſtill inflammable; but the utmoſt limits, and other particulars relating to this remarkable property of the willow-plant, are not yet fully aſcertained.

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* As this plant grows generally in water, the jar of air was inverted in the water in which the ſame grew; and, in order to keep it ſteady, it was faſtened to a ſtick fixed in the bottom of the pool; then, bending the plant, the top of it was introduced into the jar.

It has been obſerved, both by Dr. PRIESTLEY and Mr. SCHEELE, that plants do not grow ſo well in dephlogiſticated as in common air; and indeed, they generally grow better in phlogiſticated than in common air. This, as Dr. PRIESTLEY juſtly obſerves, is a great proof that plants abſorb phlogiſton from the air in the act of vegetation: ſince we ſee that when the air contains more of that principle, the plants thrive better in it; and, on the contrary, that they don't grow well in dephlogiſticated air, which contains a very little quantity of phlogiſton in compariſon to common air. We may, from this obſervation, deduce an argument to prove, that the whole ſtate of the atmoſphere has been generally the ſame as it is at preſent, in reſpect to purity, rather than to have been purer in former times, and to have afterwards gradually degenerated; for had the atmoſpherical fluid been nearer to the nature of dephlogiſticated air one or two thouſand years ago, the plants (except they have altered their nature in different times) could not have grown ſo well, and have been in ſo flouriſhing vegetative ſtate as they are at preſent; which, by all the accounts and traditions handed down to us, appears to have been not the caſe.

The numerous experiments of Dr. INGENHOUSZ, publiſhed in 1779, not only throw great light upon this ſubject of the power of plants upon air, &c. but reconcile ſeveral contradictions ſeemingly eſtabliſhed by the preceding experiments of other perſons.—The following is a conciſe account of the ſame.

I. The Doctor has obſerved that plants have a power to correct bad air, and to improve common air, in a few hours, when expoſed to the light of the ſun; but in the night-time, or in general when they are not influenced by the rays of the ſun, they contaminate common air. This property is not poſſeſſed by all ſorts of plants in an equal degree; but it is not accompanied by other viſible properties of the plants; for ſome plants, which are not reckoned very good for food, or which give a bad ſmell, poſſeſs this property in a more eminent degree than ſome other plants, which by their external appearances would be thought much preferable.—The method uſed to prove this property of plants, was the following:—A phial was filled with air, fouled either by reſpiration or by combuſtion; then a ſprig of any required plant was introduced in it, by paſſing it through the water in which the mouth of the phial was immerſed. This done, the phial was ſtopped, or it was removed from the large tub into a ſmall baſin full of water, and was expoſed to the ſun, or ſituated in ſome other place, as occaſion required.—Air fouled by breathing, in which a candle could not burn, after being expoſed to the ſun for three hours, with a ſprig of *peppermint* in it, was ſo far corrected that a candle would burn in it again. The ſame effect was produced by other plants, the particulars of which it is not neceſſary to mention, excepting one, which is very deciſive. A *muſtard*-plant was put in a glaſs receiver, containing common air, and its ſtem was cut off even with the mouth of the receiver. The receiver was then inverted in an earthen pan, containing ſome water to keep the plant alive, and the whole apparatus was ſet over-night in a room. Next morning, part of the air, being taken out of the receiver, was examined, and it was found ſo far contaminated that it extinguiſhed the flame of a wax taper. The apparatus then was expoſed to the ſun, and after a quarter of an hour, part of its air being taken out and examined, was found to be ſomewhat corrected; after one hour and half, the air was found to be conſiderably better, and after three hours it was found ſo far improved, that not only a candle burned in it, but by the nitrous taſte it appeared to be better than common air.

II. Plants not only mend bad air, but yield, out of their ſubſtance, pure reſpirable air, or dephlogiſticated air, when they are expoſed to the ſun; but in the night-time, or when they are ſcreened from that luminary, they yield very impure air.—This remarkable property of plants was proved by the Doctor in the following manner:—Either the leaves only, or the whole plants, were introduced into glaſs receivers, filled with and inverted in baſins full of pump-water *; then the apparatus was expoſed to the ſun, and the air, coming out of the pores of the leaves, formed itſelf into ſmall parcels, which grew gradually larger and larger, till they left the ſurface of the leaves and aſcended to the top of the receiver, &c. By actual trial the Doctor aſcertained that it was the light of the

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* Dr. Ingenhousz having tried different ſorts of water, as rain-water, river-water, diſtilled water, &c. found that pump-water will anſwer the beſt for thoſe experiments,

experiments, and he expreſsly recommends to uſe that water, in caſe any perſon choſe to repeat his experiments.—It is known (as diſcovered by Dr. Priestley) that pump-water, when expoſed to the ſun, gives a quantity of dephlogiſticated air: hence it might be ſuppoſed, that the dephlogiſticated air in thoſe experiments with plants was produced by the water rather than by the plants; but the Doctor removes that objection, by obſerving that pump-water by itſelf requires a long time to yield any dephlogiſticated air; ſo that if two receivers be filled with pump-water, and in one of them only be introduced ſome leaves of plants, on being expoſed to the ſun it will be found, that in a ſhort time, as about one or two hours time, a conſiderable quantity of dephlogiſticated air is accumulated into the receiver with the leaves, but in the other either there is no air at all, or an exceedingly ſmall quantity. The reaſon why no dephlogiſticated air is obtained from plants when they are introduced in receivers filled with freſh diſtilled water, the Doctor imagines to be, that the diſtilled water, not containing any elaſtic fluid, abſorbs the dephlogiſticated air as ſoon as it is produced by the plants. But then it ſhould follow, that, by afterwards boiling that water, the elaſtic fluid abſorbed, viz. the dephlogiſticated air, ſhould be ſeparated from it; this, however, does not appear to have been tried by the Doctor. Notwithſtanding the Doctor's reaſons to obviate the above-mentioned objection, it is nevertheleſs doubtful whether or no the dephlogiſticated air, at leaſt in part, may be produced by the pump-water; for although it has been obſerved by Dr. Priestley, that pump-water yields the dephlogiſticated air very ſlowly, when expoſed to the ſun by itſelf, yet we don't know how it may be affected when plants are in it, and whether, in that caſe, the direct light of the ſun can force the dephlogiſticated air out of it more eaſily.—Dr. Priestley obſerved, that when the uſual green matter began to be formed on the ſides and at the bottom of the veſſels containing the pump-water that was expoſed to the ſun, then the water yielded the dephlogiſticated air very faſt.

ſun, and not heat, that forced, as it may be ſaid, the dephlogiſticated air out of the plants. This power of yielding dephlogiſticated air is different in different plants, that is, ſome plants give more of it than others: but this, as we ſaid of their power of correcting bad air, is not conformable to their other known qualities; for the *hyoſcyamus*, the *laurocerasus*, the *night-ſhade*, the *tobacco-plant*, the *atriplex vulvaria*, the *cicuta aquatica*, and the *ſabina*, which are of a dangerous nature, were found to yield very good dephlogiſticated air. Dr. INGENHOUSZ obtained the beſt dephlogiſticated air from ſome aquatic plants, from the turpentine-trees, and eſpecially from the green matter which he collected from a ſtone trough, which was kept continually full of water, near a ſpring upon the high-road. The purity of this dephlogiſticated air is equal, if not ſuperior, to that of the pureſt ſort that is obtained by chymical proceſſes; as it ſometimes requires a quantity of nitrous air, above eight times its own bulk, before it is ſaturated, viz. before the diminution ceaſes.

III. It is not every part of the plant that improves common air, and yields dephlogiſticated air, but only the leaves and green ſtalks. The full-grown leaves yield the pureſt dephlogiſticated air, and in the greateſt quantity, eſpecially from their under ſurface.

"One hundred leaves," *ſays the Doctor*, "of *Naſturtium* "*Indicum* were put in a jar holding a gallon, filled with "pump-water; it was expoſed to the ſun in the ordinary "way, between ten and twelve o'clock, when ſo much very

“ fine dephlogiſticated air was ſettled at the inverted bottom “ of the jar; that it filled a cylindrical jar 4½ inches long, “ and 1¾ inch diameter; which air gave, by the nitrous “ taſte, 1.94; 1.82; 1.67; 1.57; 2.45½; 3.44[*].

“ All the air of theſe hundred leaves being taken away, “ they were again expoſed to the ſun, till ſeven o’clock in “ the evening, when about half the above-mentioned quan- “ tity of dephlogiſticated air was again found in the jar, “ which proved to be ſtill better than the former; its teſt “ was 1.99; 1.87; 1.73½; 1.65; 1.93½; 2.85; 3.79.

“ After ſeparating again this air from the leaves, I replaced “ the jar in the open air upon the ſame place, and left it till “ next morning at eleven o’clock, when I collected from the “ ſame leaves nearly the ſame quantity as the laſt time, of “ very fine dephlogiſticated air, ſettled at the top of the jar. “ It gave by the nitrous teſt 1.91½; 1.75; 1.58; 1.44; “ 2.20; 3.15; 3.89[†].”

The roots of plants, when kept out of ground, generally yield bad air, and at all times contaminate common air, a few only excepted. Flowers and fruits, in general, yield a very ſmall quantity of very noxious air, and contaminate a great quantity of common air at all times, eſpecially in the dark and by night *. Two dozen of young and ſmall French beans, being kept in a quart jar of common air for one night, contaminated the air to ſuch a degree, that by the nitrous taſte it gave I,I, 1.95; and a very lively chicken, about nine days old, being introduced into this air, ſhewed ſigns of the utmoſt anxiety as ſoon as it entered the jar, and died in leſs than half a minute.

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[*] It ſignifies, that to two meaſures of the dephlogiſticated air, one meaſure of nitrous air being added, after Mr. Fontana’s method, the whole was reduced to one meaſure, more $\frac{94}{100}$ of a meaſure; after adding another meaſure of nitrous air, the whole was reduced to one meaſure, more $\frac{82}{100}$; and ſo of the reſt.

[†] Experiments upon Vegetables, part ii. ſect. iv.

IV. The office of plants to yield dephlogiſticated air, begins a few hours after the ſun has made its appearance above the horizon, or rather after it has paſſed the meridian, and ceaſes with the cloſe of the day; excepting ſome plants, which continue it a ſhort time after ſun-ſet. The quantity of dephlogiſticated air, yielded by plants in general, is greater in a clear day, than when it is ſomewhat cloudy; and alſo, it is greater when the plants are more expoſed to the ſun than when they are ſituated in ſhaded places. Conſidering the whole effect of plants by night as well as by day, Dr. Ingenhousz obſerves, that the damage done by plants in the

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* There are ſome experiments of Mr. Fontana, which ſeem quite contrary to the obſervations of Dr. Ingenhousz relative to flowers; for Mr. Fontana, having kept various flowers in receivers full of air during ſeveral hours, found that the air was not injured thereby. "J'ai meme," *ſays he*, "fait quelques experiences pour voir ſi les odeurs des fleurs pouvoient alterer l'air commun. J'ai rempli de roſes, de jaſmins, de girofles, différens vaiſſeaux que j'ai tenu enfermés pluſieurs heures. L'air des recipiens ne m'a pas paru diminué ni deterioré. Les animaux l'ont reſpiré très-bien; les chandelles y ont brulé comme dans l'air commun, & l'air nitreux la diminué comme auparavant." See le Journal de Phyſique par le 1778. Supplement aux expériences ſur le fourmis.

night-time, is more than counterbalanced by the benefit they afford in the day-time. "By a rough calculation," *ſays he*, "I found the poiſonous air yielded during the whole night "by any plant, could not amount to 100th part of the "dephlogiſticated air which the ſame plant yielded in two "hours time in a fair day."

V. Laſtly, it muſt be obſerved that plants do not ſeem to produce dephlogiſticated air by a kind of generation, or by converting ſome other principle into that elaſtic fluid, but only by filtrating the common air (for plants abſorb common air †) and ſeparating the phlogiſton from it; which phlogiſton, by the joint experiments of Dr. INGENHOUSZ and others, has been evidently ſhewn to be abſorbed by plants, and to be incorporated in their nature; in which operation they do juſt the contrary of what is performed by animals, viz. plants, in their vegetation, abſorb phlogiſton from the air; whereas animals, by their reſpiration, ſeparate the phlogiſton from their bodies and give it to the air ‡.—Dry plants have very little or no power to affect common air, except they are moiſtened.

The Doctor, in the courſe of his work, conſiders ſeveral acts of providence, and wiſe combination, that are ſhewn by his above-mentioned obſervations on plants, and which open the field of admiration, and enlarge the view of a contemplative philoſophical mind.

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† See Dr. HALES's Vegetable Statics, vol. i. chap. 5.

‡ Plants do not contain the dephlogiſticated air in their own ſubſtance; for being ſqueezed under water, they either yield no air at all, or they give ſome air, at moſt, as good as common air; but it may be ſaid, that in the act of ſqueezing, the dephlogiſticated air is phlogiſticated as ſoon as produced.

By the plants counteracting the effects of animal reſpiration, combuſtion, putrefaction, &c. the atmoſpherical fluid is conſtantly kept in a proper balanced ſtate of purity. In the winter, the ſame cold, which, by hindering the vegetation of plants, puts a ſtop to the purification of the air, by that very means does, at the ſame time, hinder, in great meaſure, the corruption of ſundry matters, and conſequently the contamination of the atmoſphere. Thoſe plants grow in marſhy ground, which have the power of purifying the air in a greater degree. The weights themſelves, of dephlogiſticated and phlogiſticated air, are calculated by nature for our benefit; for the former being ſpecifically heavier than the latter, as ſoon as it is yielded by the leaves of plants, tends downwards, whereas the phlogiſticated air, by being ſpecifically lighter, tends directly upwards, and conſequently is continually receding from us.

Conſidering the above-mentioned obſervations on plants, and all the circumſtances of their natural exiſtence, it appears that the innumerable leaves of plants that are putrified about them, muſt contaminate the air to a very great degree. Computing, alſo, the number of cloudy days through the year, and the vaſt number of plants that are commonly ſhaded from the ſun; it will appear that the good office of plants upon the atmoſphere cannot be ſo very conſiderable. Yet it muſt be confeſſed, that Dr. INGENHOUSZ, purſuing the diſcoveries of Dr. PRIESTLEY, has clearly ſhewn that the vegetation of plants is one of the great means employed by nature to purify the atmoſphere, ſo as to counteract, in great meaſure, the damage done by animal reſpiration, by combuſtion, &c. It may only be ſaid, that vegetation does not appear to be ſufficient to remedy intirely that damage; and that probably nature employs other means, hitherto undiſcovered by human induſtry, which, together with vegetation, and agitation of air in water, do all contribute to that great end.

I ſhall only obſerve, in regard to Dr. INGENHOUSZ's experiments and obſervations on plants, that ſome perſons who have made ſeveral like experiments have not met, in general, with the ſame ſucceſs *. I have myſelf failed in ſome experiments of that ſort; but as mine are moſtly ſingle experiments, I ſhall defer publiſhing an account of the ſame to another opportunity, and after they ſhall have been repeated with proper attention.

Thus we have examined two methods of purifying or of meliorating common air, beſides which we are not at preſent acquainted with any other, though it is probable that nature may admit of many others, which may be diſcovered hereafter.

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* Mr. SCHEELE, in his work on air and fire, thus expreſſes himſelf:—"I have "kept vegetables in a matraſs filled with foul air, and ſhut it well (where the well-"ſhutting-up muſt be well obſerved) both in the dark and likewiſe expoſed to "the light of the ſun; I tried ſome ſmall part of this air every two days, and "always found it foul." p. 163.

The diſcovery of a method of purifying common air, by letting it paſs through a certain ſubſtance, and by this means to ſupply rooms, hoſpitals, &c. with a conſtant current of pure air, has been lately pretended, but to my knowledge the certainty of the fact could never be proved; ſo that the reader may be aſſured, that the only method to purify, or rather to remove, the tainted air of hoſpitals, ſhips, &c. that is known at preſent, is ventilation; which, as we ſaid above, is either effected by a proper conſtruction of the building, or by ventilators.

It has been already obſerved, that air attracts water and other liquors; for which reaſon it happens, that a quantity of water, or of ſeveral other liquors, being expoſed to the open air, gradually leſſens, till it is quite abſorbed by the air. This is called *evaporation*.—In common diſtillation, with a retort and a receiver annexed to it, the evaporation of fluids into the retort is effected much more eaſily, by the application of heat; for heat not only increaſes the repulſion, or rather leſſens the attraction between the particles of fluids, but alſo renders the air capable of abſorbing more vapour; for when the air is hotter, a greater quantity of watery vapour can be kept diſſolved therein, and *vice verſa*. The vapours, then, with the hot air, paſſing from the retort into the receiver, which is colder, are condenſed, and being formed into drops, fall to the bottom of the receiver. The mechaniſm of this proceſs ſeems very plain and natural; but there are ſeveral phenomena which render the explanation of it, and indeed of evaporation in general, exceedingly doubtful. That ſometimes the diſtillation of fluids with a common retort could not be effected, had been obſerved by ſeveral chymiſts; but none took the trouble to inveſtigate the right cauſe of this accidental failure, and the laws to which it was ſubject, before Mr. FONTANA undertook to perform a ſeries of accurate experiments relating to this important ſubject *. He diſcovered that the evaporation of certain fluids could not take place in veſſels hermetically cloſed, viz. out of which the communication of the external air was intirely excluded. His method, in ſhort, was to take two glaſs veſſels, or matraſſes with long necks, like G, fig. 9, plate II. into which he put the required ſubſtances, and then, by means of a lamp and blow-pipe, he joined their necks, and bent them in the form of a retort when the receiver is annexed to it, or in the form of a double barometer. Mr. FONTANA having introduced ſome vitriolic ether into one of theſe matraſſes, to the neck of which another matraſs was immediately joined, and having applied a ſand-heat to the matraſs containing the ether, obſerved that, notwithſtanding the extreme volatility of that fluid, none of it would paſs into the other matraſs.

He tried, alſo, this experiment with water inſtead of ether, with oil of vitriol and diſtilled water, and with fixed alkali and diſtilled water, viz. by putting the oil of vitriol in one and the water in the other matraſs; and in another ſimilar experiment, by putting the fixed alkali in one and the water

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* Journal de Phyſique. 1778.

in the oppoſite matraſs; he put the matraſs which contained the more evaporable fluid upon the fire, and kept the other cold; ſometimes one of the matraſſes was put in a great degree of heat, as about that of boiling water, and the oppoſite one was put into ſnow, which was changed as often as required, and in this ſituation the apparatus was kept for ſeveral days, and even weeks; it was alſo often agitated; but the evaporation never took place. The oil of vitriol, as well as the fixed alkali, notwithſtanding their great attraction to water, and their imbibing a vaſt deal of it when expoſed to the atmoſphere for a ſhort time, did never acquire the leaſt moiſture in thoſe experiments; and when, after the operation was diſcontinued, the veſſels were broke open, the oil of vitriol, as well as the very dry fixed alkali, were found to be exactly of the ſame weight they had before; ſo that not the leaſt perceivable quantity of water had paſſed through the air contained in the two matraſſes, from the veſſel in which it was put, into the oppoſite one, although the difference of heat between thoſe two veſſels was exceedingly great. Mr. Fontana obſerves, that after a long time, and when the fire was much increaſed, a little moiſture could be perceived in the neck of the veſſel containing the water, but this moiſture did reach a very ſhort way above the ſurface of the water; and alſo, that if in the courſe of the operation the veſſels were ſo far inclined as that the water in the neck of one veſſel came within a ſhort diſtance, as about an inch, of the alkali, then the alkali ſoon abſorbed part of it.

From thoſe experiments it appears, that ether and water, which evaporate very eaſily in the open air, do not evaporate at all when confined in veſſels which contain a conſiderable quantity of air, but out of which the communication of the external air is intirely excluded. Mr. FONTANA, beſides ſeveral other perſons, is inclined to think, that the evaporation of fluids is, *cæteris paribus*, ſo much the greater as the air is more rare, and that it is performed with the greateſt facility in vacuo; hence it appears, that the air in itſelf, rather than accelerating evaporation, oppoſes it with great force, except when it communicates with the common ſtock; but *query*, How is it that in thoſe circumſtances it aſſiſts the evaporation of fluids, and not when confined in a cloſe veſſel?—The preſent knowledge of philoſophy, I think, does not afford a ſatisfactory anſwer to this queſtion *.

Mr. FONTANA farther aſcertained, that the above-mentioned law, viz. of the evaporation of fluids not taking place in air not changed, or in confined air, was not extended to all fluids; but he does not pretend to determine all thoſe fluids that are not ſubject to that law; having examined only the fluid volatile alkali and the marine acid. His experiment, in ſhort, is this:—In an open ſmall phial, or in a watch-glaſs, was put a quantity of the fluid volatile alkali, and into a like glaſs was put a quantity of marine acid. Theſe two glaſſes were then carefully put at the bottom of a large glaſs bottle, ſo as to be a little way diſtant from one another, and the glaſs ſtopple was put upon the mouth of the large bottle, the juncture of which, for greater ſecurity, was covered with ſoft wax.

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* Various hypotheſes have been conceived relating to the evaporation of fluids in general, and eſpecially of water in the open air; but none quite ſatisfactory, or capable to account for all the phenomena. Some have had recourſe to capillary attraction, conſidering the atmoſphere as an aggregate of ſmall interſtices, or of capillary tubes. Others conſider evaporation to be ſimply a mechanical operation, imagining that heat forms the particles of water into ſmall veſicles, which aſcend in conſequence of their being ſpecifically lighter than the air. See Dr. DERHAM's Phyſico-Theology, Book I. Chap. 3, and Book II. Chap. 5. It has alſo been conſidered as a chymical attraction, &c. &c. See HAMILTON's Evaporation of Fluids.

Immediately on cloſing the bottle, a kind of white cloud appeared upon the marine acid, which diſappeared a ſhort time after. The apparatus being kept ſtill, in a few hours the volatile alkali appeared to be diminiſhed, and on the contrary the marine acid to be augmented in quantity. This diminution of the alkali's and augmentation of the acid's quantity became continually more and more apparent, ſo that in about one day's time almoſt the whole quantity of alkali was paſſed into the acid; and whenever the large bottle was opened, and the veſſels containing the two fluids were taken out and weighed, it was conſtantly found that the acid had acquired preciſely as much weight as the alkali had loſt; which clearly ſhews that volatile alkali can evaporate in confined air, but the marine acid cannot. In this experiment the outſide of the ſmall veſſels or watch-glaſſes, and alſo the inſide of the large bottle, were perfectly dry; and it is very remarkable, that the vapour of the volatile alkali ſhould be firſt diſperſed through the air of the bottle, and from thence ſhould be again ſeparated, and attracted by the acid.

After all, the reader may eaſily perceive, that this ſubject of evaporation is ſtill unexplained, and that a vaſt number of experiments is ſtill requiſite, in order not only to diſcover its real cauſe, but alſo to aſcertain its laws; it is, therefore, a field wherein an experimental philoſopher may exerciſe his ſkill with good hopes of ſucceſs.

In this chapter we have examined the various properties of the atmoſpherical air, but no notice has been taken of the method of producing it artificially. Indeed there is no proceſs known by which an elaſtic fluid may be obtained intirely like common air, and by itſelf. Reſpirable air may be obtained artificially, but in a ſtate much purer than that common air is generally in; and this we ſhall conſider under the title of dephlogiſticated air: as for air ſimilar to the common atmoſpheric air, it is obtained in ſmall quantity, and always together with other elaſtic fluids; thus in fixed air there is always a ſmall quantity of common air, which may be ſeparated from it by agitating the fixed air in water, till all that which is properly fixed air being abſorbed, the common air is left by itſelf in the receiver. A ſmall quantity of common air is alſo in inflammable air, and, in ſhort, in various other permanently elaſtic fluids; but we ſhall take notice of it in the chapters which treat of thoſe particular elaſtic fluids.

CHAP. II.

Of dephlogiſticated air.

THE diſcovery of a permanently elaſtic fluid, which is vaſtly ſuperior to common air in reſpect to thoſe properties of the atmoſpherical fluid, which render it abſolutely neceſſary for the greateſt natural proceſſes, as animal life and combuſtion, reflects great honour upon the preſent age, and opens a vaſt and luxuriant field of contemplation and experimental inquiry to the view of philoſophical minds.

In the works of ſome ancient authors, we find ſome faint ideas of an elaſtic fluid purer than common air, eſpecially in ſome tracts of Dr. J. Mayow, which were publiſhed at Oxford in the year 1674; but their notions were not only unwarranted by deciſive experiments, but were exceedingly confuſed, and involved in ſo many uncertainties and hypothetical ſuppoſitions, that it can hardly be ſuppoſed to have afforded any light to the modern philoſophers, who have diſcovered that admirable elaſtic fluid, and have aſcertained many of its intereſting properties.

Dr. Priestley, even in his firſt volume of Experiments and Obſervations on Air, publiſhed in 1774, ſeems to have diſcovered a permanently elaſtic fluid purer than common air; but amongſt the variety of objects in the purſuit of his experimental enquiry, he then overlooked, or rather neglected to conſider the phenomena of that fluid, which by chance were firſt preſented to his view[*]. But in his ſecond volume, publiſhed in 1776, he relates many experiments, by which the exiſtence, the method of obtaining, and ſeveral properties of an elaſtic fluid much purer than common air, were diſcovered. The firſt time that the Doctor obtained this elaſtic fluid, and obſerved its remarkable property of aſſiſting combuſtion much better than common air, was the 1ſt of Auguſt, 1774.—Common air having been proved to abſorb phlogiſton, and to become more or leſs fit to aſſiſt combuſtion, reſpiration, &c. according as it was more or leſs free from phlogiſton; it naturally followed, that the air which aſſiſted combuſtion, reſpiration, &c. better than another ſpecies of permanently elaſtic fluid, was conſidered as containing a leſs quantity of phlogiſton: hence Dr. PRIESTLEY, obſerving that his newly-diſcovered elaſtic fluid aſſiſted combuſtion much better than common atmoſpheric air, juſtly conſidered it as containing a very ſmall ſhare of phlogiſton, and gave it the name of *dephlogiſticated air*, in diſtinction from common air; which may be conſidered to have been originally of the ſame nature as dephlogiſticated air, and to have been afterwards brought down to the ſtate it is at preſent by the acceſſion of phlogiſton; though, as we have already hinted, it is very uncertain whether the atmoſpheric air was actually much purer in former times than it is at preſent.

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[*] Exper. and Obſer. vol. i. p. 155.

About the ſame time that Dr. PRIESTLEY diſcovered the dephlogiſticated air in England, Mr. SCHEELE, of Sweden, was engaged in making experiments on air and fire, which were ſoon after publiſhed in German; and in the account of thoſe experiments there is alſo the diſcovery of dephlogiſticated air, called by Mr. SCHEELE *empyreal air*; but, conſidering the views, and the courſe of experiments, both of Dr. PRIESTLEY and of Mr. SCHEELE, it appears that they were ignorant of each other's diſcoveries; whch is rather confirmed, by neither of them, or of other people acquainted with them, expreſſing any doubt about it. Upon the whole, it ſeems that Mr. SCHEELE, as well as Dr. PRIESTLEY, is entitled to the honour of the diſcovery; though Dr. PRIESTLEY appears to have been rather prior to Mr. SCHEELE.

Dephlogiſticated air is a permanently elaſtic fluid, tranſparent and inviſible, like common air, but much ſuperior to it in reſpect to its aſſiſting all the known phlogiſtic proceſſes; ſince the dephlogiſticated air can be obtained of ſuch degree of purity as to be uſeful for the reſpiration of animals, or for the combuſtion of a candle, five, ſix, and even more times than the beſt common air we can get.

There is no place yet diſcovered, upon the ſurface of the earth, where dephlogiſticated air is found naturally like fixed or inflammable air, but it may be obtained from ſeveral ſubſtances, and by various proceſſes; though it is generally yielded in conjunction with other elaſtic fluids, which however may be afterwards ſeparated from it. This pure reſpirable elaſtic fluid may be principally obtained by the following general means; viz. by expoſing nitre to a great degree of heat; by moiſtening with nitrous acid almoſt all the metallic and other earths, which contain the leaſt poſſible quantity of phlogiſton, and then heating them in proper veſſels; by only heating ſeveral ſubſtances, eſpecially metallic earths, without being previouſly moiſtened with nitrous acid; by mixing ſeveral of the above-mentioned ſubſtances with vitriolic acid, and heating them; by expoſing pump-water to the rays of the ſun; by boiling ſome kinds of water; and by expoſing the freſh leaves of plants to the rays of the ſun.

The preſent ſtate of our knowledge reſpecting elaſtic fluids in general, does not permit us to reduce the various particulars, relating to the production of dephlogiſticated air, into one or a few comprehenſive and general laws; it is therefore neceſſary to treat of each proceſs apart, and to take notice of all the remarkable phenomena attending it, and juſt mention ſome general law which they ſeem to follow. Perhaps in a few years time the happy period will arrive, in which, the natural laws reſpecting the production of dephlogiſticated air being ultimately inveſtigated, the numerous particulars at preſent noticed will be reconciled to it, and the whole will be comprehended under a few points; the fundamental laws of nature, reſpecting every ſubject, being always few and ſimple.—As nitre is the ſubſtance which yields the greateſt quantity of dephlogiſticated air, and the nature of which throws great light upon the production of dephlogiſticated air in general, we ſhall begin with the examination of this ſingular ſalt.

The reader may recollect to have been mentioned, in our Introduction to Chymiſtry, that common nitre is a neutral ſalt, containing an acid called nitrous acid, and fixed vegetable alkali.

Theſe principles have been commonly extracted by chymiſts from common nitre or ſalt-petre, and by the mixture of which artificial nitre has been formed.

By expoſing nitre in an open earthen veſſel to a ſtrong fire, its acid eſcapes, and an alkaline earth only remains. This fact has been long known to philoſophical people; but Dr. HALES ſeems to have been the firſt who, collecting the fluid which was yielded by nitre, found it to be permanently elaſtic, and tranſparent like air; but he neglected to examine it farther. Half a cubic inch of nitre, the weight of which was 211 grains, he found yielded 90 cubic inches of permanently elaſtic fluid *.

The beſt analyſis of nitre hitherto publiſhed is that made by Mr. FONTANA; which eſtabliſhes the following particulars:—If an ounce of very pure nitre is put into an earthen retort, the neck of which communicates with a large glaſs receiver, and this receiver, by means of a bent glaſs tube, that, paſſing through the water of a tub, communicates with a receiver filled with and inverted in water, in order to

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* Statical Eſſays, vol. Exp. lxxii.

collect the elaſtic fluid that comes out; and if the retort is put into a ſtrong fire, ſo as to be kept quite in a red, or rather white heat, the ounce of nitre will yield between ſeven and eight hundred cubic inches of dephlogiſticated air, the greateſt quantity of which is within the firſt three or four hours, and in about five hours time the whole quantity of air is produced; after which, the longer continuance of the fire cannot expel any more air from it. The dephlogiſticated air thus produced is not of the ſame degree of purity throughout the whole proceſs, but varies with a kind of inconſtancy; though the firſt is generally better than the laſt. Taking it at a mean, it is ſuch as that, when mixed with nitrous air, it generally gives II, I, 1, 90. II, II, 2. II, III, 2. II, IV, 3. viz. by adding ſucceſſive meaſures of nitrous air to two meaſures of the dephlogiſticated air, after the manner ſhewn in the VIth Chapter of the preceding Part, the ſpaces occupied by the mixture are, firſt one meaſure, more $\frac{90}{100}$ of a meaſure; then two meaſures; next two meaſures alſo; and laſtly three meaſures; after which, if more nitrous air be added, no farther diminution will enſue.—Theſe phenomena, viz. of the quantity and purity of the air produced, of the length of time in which it is yielded, &c. are ſubject to ſome variations, principally depending upon the intenſity of the heat applied, and upon the purity of the nitre, the pureſt yielding the moſt air.

In the glaſs receiver annexed to the retort, a red vapour appears during the firſt four or five hours of the operation, and a few grains of weak nitrous acid are collected at the bottom of it. The quantity of this acid is different, according to the different ſtrength of the heat applied; being greater when the fire is not very violent, and contrarywiſe. But the quantity of air produced follows juſt the contrary law; for when the fire is applied ſuddenly, and is very violent, a greater quantity of air, and in a ſhorter time, is obtained, than when the heat is more moderate.

The matter which remains afterwards in the retort is exceedingly ſingular for its properties, ſince it has not only loſt the properties of nitre, but ſeems to be different even from any of its known component parts. If the fire has been continued only till the whole quantity of air has been produced, the reſiduum that is found in the retort is of a greeniſh colour; but when the fire has been continued for about twenty hours, then the reſiduum is more white, and has a cauſtic alkaline taſte, and renders the tincture of violets green. It is partly ſoluble in water. By being repeatedly waſhed in water, it is rendered ſtill more white, and becomes quite inſipid. In this ſtate it effervеſces with, and is partly diſſolved in vitriolic acid. If the vitriolic acid is made to diſſolve as much of this earthy reſiduum as it can, and afterwards, being diluted with a great quantity of water, is evaporated, a ſalt will be formed which has a very peculiar taſte. If this inſipid reſiduum of nitre is mixed with nitrous or marine acid, it occaſions a ſenſible effervеſcence, and in a few minutes coagulates it like a jelly; which jelly, being dried, forms a ſalt, or rather a tranſparent ſubſtance of the conſiſtence of gum, and of the colour of amber.

The above-mentioned obſervations on nitre are applicable to the cubic nitre, the baſis of which is a mineral alkali, as well as to the common nitre, which has a vegetable alkali for its baſis *.

The moſt ſtriking phenomenon which happens in the above-mentioned decompoſition of nitre, is the converſion of its acid into dephlogiſticated air; ſince the nitre, which contains a conſiderable quantity of acid, after being acted upon by a ſtrong fire, is found deprived of all its acid part, and the ſubſtance produced from it is dephlogiſticated air, which has not the leaſt viſible mark of acidity in its nature. As for the few grains of weak acid liquor, that are found in the receiver, they are far from accounting for the phenomenon, ſince they don't amount to the hundredth part of the acid, which, by the common proceſſes, can be extracted from nitre. Though we are ignorant of the mode, we muſt confeſs that in this experiment the acid of nitre is changed into a permanently elaſtic fluid, which is not only devoid of the noxious quality of that acid, but is ſo far reſpirable and pure, that it may be reckoned to be about ſix or ſeven times better than common air †.

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* Journal de Phyſique, 1778.

† In the common proceſs of making nitrous acid, which is by diſtilling nitre with vitriolic acid, or with calcined martial vitriol, a quantity of dephlogiſticated air is produced; which may be obſerved by removing the receiver and applying a lighted candle into the neck of the retort. The candle will burn more bright towards the end of the operation than on the beginning. From an ounce of nitre and half an ounce of vitriolic acid, diſtilled together, thirty ounce meaſures of dephlogiſticated air have been obtained, beſides the nitrous acid.

My reader in this place may naturally aſk, whether any method has been diſcovered of obtaining dephlogiſticated air from the nitrous acid itſelf?—This has been done by Mr. SCHEELE, who, by diſtilling the fuming nitrous acid by itſelf, obtained a quantity of dephlogiſticated air; but as the ſame experiment, being repeated by ſeveral philoſophical perſons, has not been attended with the ſame reſults as are mentioned by the author of it, I ſhall here relate it in Mr. SCHEELE's own words, for the ſake of thoſe who are willing to inveſtigate the cauſe for which it has not ſucceeded with ſeveral perſons.

" I took a glaſs retort, capable of containing eight ounces " of water, and diſtilled fuming ſpirit of nitre, according to " the uſual methods.

" In the beginning the acid paſſed over red, then it became " colourleſs, and laſtly again all red: no ſooner did this " happen, than I took away the receiver; and tied to the " mouth of the retort a bladder emptied of air, which I had " moiſtened in its inſide with milk of lime, *lac calcis*, " *(i. e.* lime-water, containing more quick-lime than water " can diſſolve) to prevent its being corroded by the acid. " Then I continued the diſtillation, and the bladder gra- " dually expanded. Hereupon I left every thing to cool, " tied up the bladder, and took it off from the mouth of the " retort.—I filled a ten-ounce glaſs with this air, and put a " ſmall burning candle into it; when immediately the " candle burned with a large flame, of ſo vivid a light that

" it dazzled the eyes. I mixed one part of this air with " three parts of air wherein fire would not burn; and this " mixture afforded air in every reſpect ſimilar to the common ſort *."

The obſervations hitherto made, relative to the natural production of nitre, are, that this ſalt owes its origin partly to vegetable and animal ſubſtances, and partly to air; ſince it is never found, except in places in which animal matters have ſtood, or ſometimes where vegetable ſubſtances are left to putrefy, and generally upon the ſurface of the earth, or very near it; viz. where the air had acceſs. The few inſtances of pieces of ſalt-petre ready formed being found under ground, and the ſmall quantity of nitre which may be extracted from a few plants, are frivolous objections againſt the general obſervations; ſince it may be eaſily conceived, that the nitre previouſly formed may, by ſome unuſual accident, have been buried deep under ground, in particular and very rare inſtances, &c. It ſeems, therefore, very likely that the alkaline or earthy baſis of nitre acquires its acid, by which it is neutralized, from the atmoſphere, or rather by converting the pureſt part of atmoſpheric air into nitrous acid; from which it follows, that the pureſt part of common air, or that dephlogiſticated air, is eſſentially the acid of nitre, though diveſted of all the properties which characterize that acid.— This is an intereſting inveſtigation, but we ſhall defer to treat more fully of it to another Part of this work. It is only

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* Scheele's Exper. on Air and Fire, p. 34.

neceſſary to mention here ſome obſervations relating to the effects of nitre on common air, which throw ſome light upon this ſubject. Dr. PRIESTLEY diſſolved as much nitre in a quantity of water as it poſſibly could when hot, and then left it to cool under a receiver ſtanding in water; but he found that the air of the receiver was not ſenſibly altered by the cryſtallization of the nitre *.

The ſame philoſopher kept nitre in a crucible over the fire "till," *ſays he*, "all the air ſeemed to be expelled from it," then, introducing it under a receiver inverted in water, left it to cool, and the day after examining the air of the receiver, found it to be not ſo good as common air. "It was re-"markable," *ſays he*, "however, that after theſe mixtures" *(meaning of common with nitrous air, and of the air of the receiver with nitrous air)* "had remained a day and a night, "they approached nearer to an equality. This, alſo, I ob-"ſerved more than once, and am much ſurprized at the fact. "It ſhould ſeem that the air to which this nitre had been "expoſed, was not abſolutely ſo much injured as the firſt "mixture of nitrous air with it would ſhow; but that its "conſtitution was ſo much altered, that it required more "time for the phlogiſton diſcharged from the nitrous air to "act upon it †."

The Doctor alſo melted ſome ſalt-petre in a glaſs veſſel, and afterwards expoſed it to a quantity of common air, and about a week after found that that air had been injured conſiderably [*].

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* Exper. and Obſer. vol. i. p. 161.

† Ibid. vol. ii. p. 166.

Although dephlogiſticated air has not been extracted from nitrous acid alone, by any other perſon, as far as I am informed, beſides Mr. SCHEELE, yet, by moiſtening ſeveral ſubſtances with that acid, and expoſing them to a ſufficient degree of heat, dephlogiſticated air may be obtained, though moſtly mixed with other permanently elaſtic fluids. In general, it ſeems that dephlogiſticated air may be obtained, more or leſs, from all kinds of earth mixed with nitrous acid, and that the metallic and calcareous earths ſeem to furniſh the greateſt quantity of it.

Dr. PRIESTLEY diſſolved ſome gold in common *aqua regia*, which is made with one part of marine and three parts of nitrous acid; and afterwards diſtilling this ſolution to dryneſs, obtained about half an ounce meaſure of air [†], the half of which quantity was pure dephlogiſticated air, and the reſt ſeemed to be an acid vapour, that was abſorbed by lime-water, without occaſioning any precipitation of the lime in it [‡].

From a ſolution of ſilver in diluted nitrous acid, Dr. PRIESTLEY obtained ſome nitrous air, and afterwards, by the application of a ſand-heat, a ſmall quantity of very pure air was produced [‡].

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[*] Exper. and Obſer. vol. ii. p. 166.

[†] By an ounce meaſure Dr. PRIESTLEY underſtands the ſpace occupied by an ounce meaſure of water, which weighs 480 grains.

[‡] PRIESTLEY's Exper. and Obſer. vol. iii. ſect. 1.

Having diſſolved as much quickſilver in nitrous acid as it was poſſible without heat, the ſolution ſeparated from the undiſſolved mercury was put into a veſſel in a ſand-heat, and it yielded firſt nitrous and then about an equal quantity of dephlogiſticated air. " During the rapid pro-" duction of this air, it was exceedingly white, and the " tube through which it was conveyed was very red with the " redundant nitrous vapour. Towards the end of the proceſs " the tube was tranſparent and colourleſs, though the air " burſt in white clouds within the receiver *."

A ſolution of mercury in vitriolic acid, being mixed with nitrous acid, efferveſced very much, generating nitrous air; but afterwards the veſſel that contained it being put into a ſand-heat, ſome elaſtic fluid was produced, the firſt of which was fixed air, which was followed by a large portion of nitrous, after which ſome dephlogiſticated air was produced *.

From the calx of copper, made by diſſolving it in vitriolic acid, after moiſtening it with nitrous acid, ſome fixed air was firſt obtained, then ſome nitrous air, and laſtly ſome dephlogiſticated air †.

When copper is diſſolved in nitrous acid, the produce is nitrous air; but if the ſolution is afterwards diſtilled to dryneſs,

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* PRIESTLEY's Exper. and Obſer. vol. iii. ſect. 1.

† This proceſs was made with a gun-barrel, into which the calx of copper was put, and to whoſe muzzle a bent tube was cemented, which conveyed the produced elaſtic fluid under the inverted receiver.

neſs, ſome dephlogiſticated air will be produced, though mixed with fixed air[*].

From ſome very dephlogiſticated calx of iron, moiſtened with nitrous acid, Dr. PRIESTLEY alſo obtained ſome very pure dephlogiſticated air, mixed with a very ſmall portion of fixed air[*].

All the calxes of lead, when moiſtened with nitrous acid, and by the application of heat, yield dephlogiſticated air, though always mixed with more or leſs fixed air. In general, the more deprived of phlogiſton is the calx, the leſs fixed air is obtained from it.

Before I proceed farther, it will be proper to remark, that the calxes of metallic ſubſtances in general, and ſome of them more than others, eſpecially the calx of iron, are very difficultly deprived of phlogiſton, at leaſt of that quantity of it which is neceſſary to render them fit for the production of dephlogiſticated air. Dr. PRIESTLEY has a particular method, which anſwers exceedingly well, for the dephlogiſtication of the metallic calxes. "This," *ſays he*, "is effected by "diſſolving the metals completely, and diſtilling the ſolution "to dryneſs in a glaſs veſſel, employing more ſpirit of nitre, "till as much as I pleaſe of it be converted into air. If "much phlogiſton do not adhere to the calx of the metal, "pure air will be produced at the very firſt diſtillation; but "if the air be very impure, by containing much phlogiſton,

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[*] PRIESTLEY's Exper. and Obſer. vol. iii. ſect. 1.

" the whole of the firſt produce will be nitrous or phlo-" giſticated air, and pure air may not be procured till the " ſecond or third proceſs †."

Dr. Priestley put five penny-weights ſix grains of tin into ſome diluted nitrous acid, which was diſſolved with great violence, and generated " about fifteen ounce meaſures of " air, about one fifth of which was abſorbed by water, being " the nitrous vapour, ſo often mentioned above, diffuſed " through the air. Before this part was waſhed out, a candle " burned in the air naturally; but when this part had been " abſorbed by the water, a candle went out in it. The " former part of the produce, which was ¾ of the whole, was " but ſlightly nitrous; for two meaſures of common air and " one of this occupied the ſpace of 2½ meaſures; and the " laſt part was proper phlogiſticated air, neither affecting " common air, nor being affected by nitrous air. Had I " taken the produce in ſmall portions, the firſt produce " would, I doubt not, have been proper nitrous air, as I had " firſt found. I particularly obſerved, that no part of this air, " though readily abſorbed by water, made lime-water turbid, " ſo that it contained no fixed air.

" After this, diſtilling the reſiduum to dryneſs in a glaſs " phial with a ground ſtopple, I got about twelve ounce " meaſures of air, in four parts; of which a portion of " each, and eſpecially at the firſt, was readily abſorbed by

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† Exper. and Oſerv. vol. iii. ſect. 1.

" water, but without making lime-water turbid. When " this ingredient was waſhed out, the air which had lodged " within the phial was phlogiſticated. Then the firſt portion " of the proper produce of the materials was common air, " the ſecond twice as good, and the remaining portions were " exceedingly pure †."

It is remarkable, that in this proceſs with tin no fixed air is produced; but adding ſome more ſpirit of nitre upon the above-mentioned reſiduum, the Doctor obtained about twice its bulk of air, part of which was fixed air.

This proceſs with tin having been repeated by ſeveral perſons, has been attended with various reſults, though upon the whole they are principally the ſame thing.

From about half an ounce of flowers of *zinc*, moiſtened with ſpirit of nitre, and put into a glaſs phial with ground ſtopple and tube, Dr. PRIESTLEY obtained about three pints of very pure dephlogiſticated air ‡. In this proceſs the dephlogiſticated air is generally very turbid when firſt produced, and every bubble of it that comes through the water, ſhews the appearance of a cloud, as it were, of white duſt, within the receiver. Indeed this turbid or cloudy appearance is obſervable alſo in ſome other proceſſes for obtaining dephlogiſticated air, eſpecially with the calx of lead, though not ſo much as with the flowers of zinc.

Biſmuth, when treated with ſpirit of nitre as above-mentioned, at laſt yields a conſiderable quantity of pure dephlogiſticated air. “Putting,” *ſays Dr.* Priestley, “the “ſalt formed by the ſpirit of nitre, and biſmuth, into a “glaſs veſſel, and diſtilling it to dryneſs, with a ſand-heat, I “procured from it about twenty times its bulk of air, in the “firſt part of which there was ſome fixed air; but all the “reſiduum was pure dephlogiſticated air, eſpecially at the “laſt *.”

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† Exper. and Obſer. vol. iii. ſect. 1.

‡ Ibid. vol. ii. ſect. 4.

A mixture of antimony with ſtrong nitrous acid, after it had ſtayed till it became a whitiſh ſubſtance, (which will take place after ſome days, and during which time it gave no permanently elaſtic fluid of any ſort) being put into a proper glaſs veſſel, and by means of a ſtrong ſand-heat, it yielded about ten times its bulk of elaſtic fluid, one third of which was fixed, and the reſt was dephlogiſticated air *.

In theſe proceſſes it is generally obſervable, that the portion of air that is produced towards the laſt is more pure than that which is produced before; a leſs portion of fixed air being mixed with it.

The above-mentioned particulars relating to metallic ſubſtances have been inſerted, not only for the ſingular phenomena which they exhibit, but alſo to give a kind of ſtandard, to which the ingenious reader may compare his experiments.

Now for the general production of dephlogiſticated air.—

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* Exper. and Obſer. vol. iii. ſect. 2.

The numerous experiments hitherto made ſeem to eſtabliſh that dephlogiſticated air may be obtained from all ſorts of ſubſtances, whether vegetable, animal, or mineral, when mixed with nitrous acid, and expoſed to a ſufficient degree of heat; provided thoſe ſubſtances be firſt deprived of phlogiſton †. Thus the aſhes of vegetables, or of animal matters, the calxes of metals, the various ſorts of earths, eſpecially the calcareous, powdered flint, and even powdered glaſs, when mixed with nitrous acid, produce dephlogiſticated air, though generally mixed with fixed air. In ſhort, the theory of the production of the permanently elaſtic fluid from thoſe ſubſtances ſeems to be as follows:—Subſtances of every ſort, when mixed with nitrous acid, and acted on by a ſufficient degree of heat, produce an elaſtic fluid, which, if the ſubſtance contains much phlogiſton, is nitrous air; if the quantity of phlogiſton contained is very ſmall, the elaſtic fluid produced is fixed air; and if the ſubſtance is very much dephlogiſticated, the produce is pure dephlogiſticated air. But when a ſmall quantity of phlogiſton exiſts in the ſubſtance uſed, the fixed and dephlogiſticated air generally come out together.

To this theory the following phenomenon ſeems to be irreconcileable, though at the ſame time it is not quite contrary to it.—*Red precipitate*, which is formed by boiling mercury and nitrous acid together for a conſiderable time, when expoſed to a ſtrong degree of heat in a proper veſſel, yields a great quantity of pure dephlogiſticated air, and at the ſame time the quickſilver is revivified into running mercury, which is generally ſuppoſed to contain, like other metallic ſubſtances, a conſiderable ſhare of phlogiſton.

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† It is only to be remarked, that from ſome ſubſtances more of it can be obtained than from others; the advantage being on the ſide of the metallic calxes and calcareous earths.

Upon the ſuppoſition that the dephlogiſticated air is produced from the nitrous acid mixed with thoſe ſubſtances (which, for very good reaſons, to be mentioned preſently, ſeems to be, in great meaſure, if not wholly the caſe) the production of dephlogiſticated air from red precipitate may be attributed intirely to the acid; and in ſo much this permanently elaſtic fluid is not become nitrous or fixed air, as the phlogiſton, which exiſts in the ſubſtance of the quickſilver, is ſo intimately connected with the other components of that metal, that nothing of it can be ſeparated from the baſis with which it is connected.

That, in many inſtances, the quantity of dephlogiſticated air that is produced depends upon the quantity of nitrous acid uſed in the proceſs, has been pretty clearly proved. Dr. PRIESTLEY having moiſtened equal quantities of red-lead with unequal quantities of nitrous acid, found that the greateſt quantity of dephlogiſticated air was produced by that portion of red-lead with which a greater quantity of nitrous acid had been mixed; the quantities of dephlogiſticated air produced being nearly proportional to the quantities of acid.

But notwithſtanding that in moſt caſes the dephlogiſticated air ſeems to be clearly produced from the nitrous acid, and that Mr. SCHEELE has produced dephlogiſticated air from the nitrous acid itſelf, without the intervention of any other ſubſtance; yet it is certain, from a variety of experiments, that the dephlogiſticated air is not only the produce of nitrous acid only, but that ſeveral ſubſtances yield it independent of that acid, and when they are acted upon by heat only, or by the vitriolic acid. Thus *precipitate per ſe*, by means of heat only, yields dephlogiſticated air *. Mr. FONTANA having rendered ſome *precipitate per ſe* very dry, by keeping it in a ſmall degree of heat for ſeveral hours, weighed 192 grains of it, and introduced this quantity into a glaſs phial, having a long and bent tube, as already deſcribed: Then, applying a ſufficient degree of heat under it, received the air into a glaſs jar filled with and inverted in a trough of quickſilver. The bulk of dephlogiſticated air produced by this quantity of precipitate per ſe was 26½ cubic inches, which was yielded without the leaſt mixture of fixed air; and the mercury was at the ſame time revivified, and its weight was found to be 178⁸⁄₉ grains, ſo that it had loſt 13⅑ grains, which is pretty nearly the weight of the dephlogiſticated air that was generated [†].—It being known that when quickſilver is turned into precipitate per ſe it augments in weight, it ſeems evident that the mercury, on the act of becoming precipitate per ſe, abſorbs from the atmoſphere the pure dephlogiſticated part of it, which augments its weight, and which comes out in the form of dephlogiſticated air, without any mixture of fixed air, when the precipitate per ſe is turned into running quickſilver. Though we are much in the dark reſpecting the nature of the precipitate per ſe, and have no idea of the manner with which mercury can enter into combination with air, we are nevertheleſs certain, that the communication with the atmoſphere is neceſſary for the converſion of mercury into precipitate per ſe; for it cannot be effected in veſſels hermetically ſealed; and that it does not abſorb any fixed air [‡].

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* The reader may recollect, that the precipitate per ſe is formed by expoſing quickſilver only to a pretty ſtrong ſand-heat, for ſome months, in glaſs veſſels having a longiſh open neck.

Red-lead, either by heat only, or by means of vitriolic acid, yields dephlogiſticated air together with fixed air. If the red-lead is put into a glaſs veſſel filled with and inverted in quickſilver, (in which caſe the red-lead will go to the upper part, viz. to the inverted bottom of the veſſel) and the focus of a lens is thrown upon it, the red-lead will yield about ten times its own bulk of elaſtic fluid; one third part of which is fixed, and the reſt dephlogiſticated air. If the red-lead is put into a glaſs phial with ground ſtopple and tube, and ſome vitriolic acid is poured upon it, a good deal of elaſtic fluid will be produced, the firſt part of which is moſtly fixed air, but the greateſt part, that is afterwards yielded, is dephlogiſticated air. Although part of the elaſtic fluid in this proceſs is produced without any application of heat, it is yet neceſſary to apply the flame of a candle under the phial, in order to obtain the greateſt quantity of it. When this experiment is performed for the ſake of obtaining ſome quantity of dephlogiſticated air, it being a very expeditious way, the beſt method is to receive the whole produce of elaſtic fluid in one veſſel; for afterwards, by agitating the ſame in water or lime-water for a ſhort time, the fixed air is abſorbed, and the dephlogiſticated air remains pure *.

[†] See Recherches Phyſiques ſur la nature de l'air nitreux, et de l'air dephlogiſtiqué, par l'Abbé Felix Fontana, p. 117.

[‡] Ibid. p. 131.

The quantity of dephlogiſticated air obtainable by this means from red-lead is various, according to the various ſpecimens of that ſubſtance; and it is remarkable, that old red-lead yields more of it than ſuch as has been newly made; which ſhews that red-lead, like the precipitate per ſe, abſorbs the dephlogiſticated air, or that ſubſtance which forms it, from the atmoſphere.—Indeed red-lead cannot be made except with the acceſs of air. Perhaps the reaſon why old

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* Mr. J. Warltire, in a letter to Dr. Priestley, mentions to have obſerved, that when the red-lead is previouſly moiſtened with nitrous acid, and then ſtrong vitriolic acid is poured upon it, the dephlogiſticated air is diſengaged ſuddenly from the materials, in a conſiderable quantity, and without the application of any extraneous heat. Its quality is alſo ſuperior to that obtained without the intervention of nitrous acid. Exper. and Obſer. vol. iii. p. 366.

red-lead contains more dephlogiſticated air than that newly made, is becauſe red-lead is not ſo pure a calx, when juſt made, but contains ſtill a conſiderable ſhare of phlogiſton; which, by mere expoſure to the air for a long time, is continually imparted to the atmoſphere, and at the ſame time, in proportion as the red-lead loſes gradually its phlogiſton, it acquires the dephlogiſticated air.—Different applications of heat have alſo different effects upon red-lead *.

By means of heat only, ſome dephlogiſticated air may be obtained from *ſedative ſalt*; but the quantity it yields is very ſmall, in general not exceeding the bulk of the materials, and the quality is ſuch, that ſometimes it is not purer than common air.

Beſides thoſe already mentioned, dephlogiſticated air may be obtained from ſeveral other minerals. From an ounce of *mangane ſe*, finely powdered, Dr. PRIESTLEY, by a red ſand-heat, obtained 40 ounce meaſures of air, part of which, eſpecially at the firſt, was fixed air, but four fifths of the laſt was very pure dephlogiſticated air †. After the experiment,

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[*] "From equal quantities of the ſame red-lead, without any mixture of ſpirit "of nitre, and uſing the ſame gun-barrel, I got, by means of heat ſuddenly "applied, more air than I got by heat applied ſlowly, in the proportion of *ten* to "*ſix*. The proportion of fixed air was the ſame in both caſes, and the remainder "equally dephlogiſticated." PRIESTLEY's Exper. and Obſer. vol. iii. p. 37.

[†] In this, and in ſimilar experiments, the Doctor uſed ſmall bellied retorts of green glaſs, which can ſtand the fire beſt, containing about an ounce of water, and having very long and narrow necks about eighteen or twenty inches long. Into theſe retorts he put the ſubſtance to be examined, and then expoſed them

the *manganeſe* was found to have loſt 1½ dwts. of its weight, but it was ſtill black as before. A conſiderable quantity of water came over during this proceſs *.

From one ounce of *lapis calaminaris* finely powdered, by a red-hot ſand-heat, 316 ounce meaſures of air were produced, four ounce meaſures of which was dephlogiſticated air, the reſt was fixed air. It is remarkable, that the reſiduum, after that this fixed air had been abſorbed by water, was as good as common air *.

From an ounce of the mineral called *wolfram*, treated like the above-mentioned lapis calaminaris, after a long-continued heat, not more than one ounce meaſure of air was produced, a ſmall part of which was fixed air, and the reſt was about as good as common air *.

Dr. PRIESTLEY diſſolved 6 dwts. of very clean iron in oil of vitriol, and then diſtilled the ſolution to dryneſs in a long-necked retort. "I received," *ſays he*, "the common air a "little phlogiſticated, a little fixed air, much vitriolic acid "air, and laſtly 18 ounce meaſures of dephlogiſticated air. "The iron that remained undiſſolved weighed 23 grains, ſo "that the air was yielded by 5 dwts. 1 grain, of iron. "The ochre weighed 7 dwts. 13 grains, ſo that there "probably remained a quantity of oil of vitriol in the ochre;

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to a red-heat, either in ſand or over a naked fire, while their necks were plunged in water or mercury. Exper. and Obſer. vol. iv. p. 202.

* Exper. and Obſer. vol. iv. ſect. 20.

" and conſequently, had the heat been greater, more air " might have been procured *."

The Doctor having aſcertained, that by repeated additions of nitrous acid upon ſeveral ſubſtances, more and more dephlogiſticated air could be obtained, examined whether the ſame effect would take place with vitriolic acid. To this effect, he added more oil of vitriol to the reſiduum of the above-mentioned experiment with iron, " and then with a red heat, in " a glaſs retort, it yielded a quantity of vitriolic acid air, no " fixed air, but 24 ounce meaſures of dephlogiſticated air; " when, the retort being melted, a good deal of the air was " neceſſarily loſt; for the produce of air had not begun to " ſlacken when this accident happened, and, removing the " retort from the fire, I found only about half of the matter " turned red, while the remainder was white. From this " circumſtance I concluded, that before I had not got half " the air that it would have yielded. Reſuming the proceſs " in a gun-barrel, I actually got about as much air as I had " done before.

" I had not now the leaſt doubt remaining, but that the " acid of vitriol, at leaſt with iron, is capable of properly " *generating* dephlogiſticated air, as well as the acid of nitre " with lead, or any ſubſtance whatever †."

Upon an ounce of common ruſt of iron, Dr. PRIESTLEY poured ſome vitriolic acid, which was ſoon imbibed by the ruſt; then uſing a gun-barrel, he obtained from it two or three pints of fixed air, but which contained a large reſiduum, viz. about one third of phlogiſticated air. "As the common ruſt of iron," *ſays he*, "contains a good deal of "phlogiſton, I did not expect any better reſult from this "experiment. But having, in ſome meaſure, purified it by "this proceſs, I put more oil of vitriol to what remained of "the ruſt of iron, and then I got from it only a little fixed "air, and ſixteen ounce meaſures of dephlogiſticated "air *."

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* Exper. and Obſer. vol. iv. ſect. 20.

† Ibid. ſect. 21.

From about half an ounce of blue vitriol, in a glaſs veſſel, Dr. Priestley obtained a little fixed air, and one ounce meaſure of dephlogiſticated air; but the glaſs veſſel breaking, he put the materials into a gun-barrel, and then they yielded about 25 ounce meaſures of dephlogiſticated air, with hardly any more fixed air †.

Having put half an ounce of copper in oil of vitriol, part of which only was found diſſolved after the proceſs (for that which was firſt diſſolved formed a cruſt over, and defended the reſt of the metal;) and having put this half ounce of copper, with the oil of vitriol, into a glaſs retort; Dr. Priestley diſtilled it to dryneſs, and obtained from it, beſides vitriolic acid air, ſome fixed air, and but one ounce meaſure of dephlogiſticated air. The glaſs retort being melted, he introduced the materials into a gun-barrel; and, by a ſtrong fire urged by a pair of bellows, he obtained about one ounce meaſure of fixed air, and about ten times as much dephlogiſticated air *.

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* Exper. and Obſerv. vol. iv. ſect. 21.

† Ibid. vol. iv. ſect. 22.

From an ounce of calcined *white vitriol* in a gun-barrel, the Doctor obtained a great quantity of vitriolic acid air, ſome fixed air, and five ounce meaſures of dephlogiſticated air *.

A quantity of oil of vitriol being put upon half an ounce of flowers of *zinc*, and then theſe materials being introduced into a gun-barrel in a ſtrong fire, they yielded three ounce meaſures of elaſtic fluid, a ſmall part of which was fixed air, and the remainder was nearly as good as common air. But Dr. PRIESTLEY, who made this experiment, obſerves, that had he made uſe of a glaſs veſſel inſtead of the gun-barrel, he would, in all probability, have obtained a much greater quantity of elaſtic fluid, and of a purer ſort; it being certain, that whatever tends to injure good air, leſſens alſo the quantity of it *.

The Doctor had no ſucceſs with ſilver, " owing, perhaps," *ſays he*, " to its requiring more heat than I could apply in a " glaſs veſſel *."

Mercury, diſſolved in vitriolic acid, and the ſolution expoſed to a ſtrong heat, in a glaſs retort, and diſtilled to dryneſs, yields firſt a good deal of vitriolic acid air mixed with ſome fixed air, and then ſome dephlogiſticated air.

From an experiment of Dr. PRIESTLEY's it appears, that from an ounce of mercury, diſſolved in two ounces of vitriolic acid, the quantity of dephlogiſticated air obtained was 21 ounce meaſures; but it ſeems that this was not the whole quantity that might be obtained, ſince the proceſs was interrupted by the melting of the retort *.

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* Exper. and Obſer. vol. iv. ſect. 22.

" It is remarkable," *ſays Dr.* PRIESTLEY, " that either by " means of oil of vitriol, or ſpirit of nitre, quickſilver yields " a very great quantity of dephlogiſticated air; but with this " difference, that in the proceſs with ſpirit of nitre, almoſt " the whole of it (that is, if the proceſs be conducted with " care, with the loſs of not more than the twentieth part of " the mercury) is revivified, and therefore may be uſed again " and again; whereas, in the proceſs with the oil of vitriol, " almoſt all the mercury is loſt *."

From an ounce of pure white calx of tin, called *putty*, and oil of vitriol, Dr. PRIESTLEY obtained a little fixed air, with about three ounce meaſures of phlogiſticated air; but he attributes the non-production of dephlogiſticated air to the gun-barrel employed, which may probably have imparted phlogiſton to the produced elaſtic fluid *. Indeed it it is a great deſideratum in philoſophy, to find a ſubſtance capable of being formed into retorts, or other like veſſels, and which might ſuſtain a very great degree of heat, and at the ſame time was not affected by acids.

Beſides the metallic earths, dephlogiſticated air may be obtained alſo from other earthy ſubſtances, when mixed with vitriolic acid, though in ſmall quantity. *Alum* by itſelf gives fixed air, and a ſmall quantity of air which is generally a little better than common air; but when it ceaſes to give any elaſtic fluid by itſelf, if oil of vitriol is added to it, and then expoſed to a ſtrong heat in a proper veſſel, it yields a little more elaſtic fluid, which conſiſts of fixed air and a ſmall portion of reſpirable air.

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* Exper. and Obſer. vol. iv. ſect. 22,

Quick-lime, moiſtened with oil of vitriol, and expoſed to a very ſtrong degree of heat, yields a conſiderable quantity of fixed air, and a ſmall portion of reſpirable air of about the ſame degree of purity as common air.

" *Mangan*e*ſe*," *ſays Dr.* PRIESTLEY, " yielding dephlogiſticated air without the help of any acid, it might be " thought more proper for the production of air with that " aſſiſtance, as *minium* is with reſpect to the nitrous acid. I " therefore tried it on the 15th of April; when, to one ounce " of this ſubſtance, (which had been kept red-hot a long " time on the 10th of November preceding) I put ſome oil " of vitriol, which it imbibed eagerly, and then got from it " about 12 ounce meaſures of air, the whole of which was " fixed air, except about one ounce meaſure, which was " about as good as common air. In this experiment I " believe I made uſe of a gun-barrel; ſo that, probably, more " and better air would have been procured in a glaſs veſſel *."

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* Exper. and Obſer. vol. iv. ſect. 23.

In reſpect to the extraction of dephlogiſticated air from any ſubſtance by means of marine acid, I find only one ſatisfactory experiment, which is of Dr. PRIESTLEY; who having diſſolved a quantity of *minium* in ſpirit of ſalt, diſtilled the ſolution, and obtained from it a quantity of dephlogiſticated air with a ſmall portion of fixed air [*].—Upon the whole, it appears that various ſubſtances contain dephlogiſticated air, or ſome ſort of matter which can aſſume the form of a permanently elaſtic fluid much purer than common air; that the production of this elaſtic fluid may be effected by means of heat, and by the action of the nitrous or vitriolic acid; and that ſome ſubſtances, which do not yield any dephlogiſticated air by means of heat only, may be rendered capable of yielding ſome of that elaſtic fluid, by adding the vitriolic, and eſpecially the nitrous acid to them. This laſt obſervation ſeems to ſhew, that the two acids, namely the vitriolic and the nitrous, may be changed into dephlogiſticated air; upon which ſuppoſition, thoſe two acids would appear to be originally the ſame thing, ſince either of them may be turned into the ſame kind of ſubſtance. But if the above-mentioned obſervations are duly conſidered, it will appear, that although ſeveral ſubſtances, which do not yield any dephlogiſticated air of themſelves, when mixed with vitriolic acid are capable of producing ſome of it, yet it may be, that they contain in themſelves the dephlogiſticated air, which the force of heat only cannot expel from them; but that the vitriolic acid, weakening the attraction between the parts of thoſe bodies and of the dephlogiſticated air, renders the latter capable of being eaſily expelled by fire. The bodies employed remaining, after thoſe experiments, of nearly the ſame weight as they were before, is neither a ſatisfactory phenomenon; ſince the weight loſt by the eſcape of the dephlogiſticated air from thoſe bodies may be ſupplied by the vitriolic acid, or by the water it contains. Notwithſtanding that thoſe obſervations are, in great meaſure, applicable to the experiments with the nitrous acid, yet it ſeems aſcertained that the nitrous acid may aſſume the form of dephlogiſticated air, if not by itſelf, at leaſt in conjunction with ſomething elſe, of which hitherto we have no preciſe idea. The experiments with the calx of lead, moiſtened with nitrous acid, together with ſeveral other experiments of the like nature, render it highly probable; but the production of dephlogiſticated air from nitre, in which caſe all its acid part is loſt, and Mr. Scheele's experiment of obtaining dephlogiſticated air from nitrous acid itſelf, render it as certain as it can be expected in experimental philoſophy, viz. that the acid of nitre may become dephlogiſticated air, or at leaſt one of it components.

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[*] Exper. and Obſer. vol. iv. p. 442.

From this it follows, that dephlogiſticated air is an acid; but as it ſhows none of the general properties of acids, and being very far from having any offenſive quality, it muſt be mixed with ſome other ſubſtance, which renders it mild, or, as it may be ſaid, neutralizes it.—This conſideration leads to many concluſions that are very intereſting in the ſubject of this work; but we ſhall defer examining it farther till after we have taken notice of the other methods of obtaining, and of ſome other properties of dephlogiſticated air.

Among the other ſources of dephlogiſticated air, the reader may recollect to have been mentioned, in the preceding Chapter, that green plants, when expoſed to the direct light of the ſun, do yield dephlogiſticated air: Dr. PRIESTLEY, having examined the bladders that are formed on ſeveral plants, has often found that the permanently elaſtic fluid they contained, was purer than the common air. The Doctor having examined the air contained in the hollows of the *bladder ſena*, and of the ſtalks of onions, found it ſometimes of the ſame degree of purity with common atmoſpheric air, and ſometimes a little worſe. With the air extracted from the bladders of certain ſea-weeds, thrown by the waves upon the ſea-ſhore, he had nearly the ſame ſucceſs; but gathering once the young and freſh plants that were actually growing under the ſea-water, and preſſing the air out of their bladders in a tub of water, he collected it into an inverted receiver, and, examining it by the nitrous taſte, found it to be purer than common air, ſince it gave I,I, 1,1, whereas common air gave I,I, 1,35.—The manner in which the air comes to be lected in thoſe bladders is deſerving of inveſtigation.

It has been mentioned in the preceding Chapter, that various ſorts of water contain ſome pure reſpirable air, which, by boiling, may be extracted from them; and it has been alſo ſhewn, that the water out of which the air has been extracted by boiling, or by the air-pump, when expoſed to the atmoſphere, abſorbs the pureſt part of it, leaving back the more phlogiſticated portion. But Dr. PRIESTLEY has made ſeveral intereſting diſcoveries relative to the ſpontaneous emiſſion of pure air from water; which, for ſhortneſs ſake, I ſhall here collect under a few principal and comprehending heads. I. If a glaſs receiver filled with, and inverted into, a baſin of pump-water, is expoſed to the light of the ſun, that quantity of water will, in general, yield about one ounce meaſure of dephlogiſticated air for every 15 ounces of water, and that in about one month's time; the air being collected at the top, or inverted bottom of the receiver. It is very remarkable, that heat without light will not have the ſame effect upon pump-water; "and though, when water is once prepared by expoſure "to the ſun, warmth will ſuffice to *expel* that air; yet, in "this caſe, the air has never been ſo pure as that which has "been yielded ſpontaneouſly, without additional heat." The quantity of air that is expelled from pump-water by heat only, is alſo leſs in quantity than that which it yields by expoſure to the ſun. II. The pump-water does not ſeem to begin to yield any air till ſome greeniſh matter is formed on the inſide of the inverted veſſel; which ſeems to ſhew as if the dephlogiſticated air was produced from the green matter rather than from the water *. "But," *ſays Dr.* PRIESTLEY, "I preſently

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* In regard to the green matter that is uſually formed on the ſides and at the bottom of veſſels containing pump-water, the Doctor obſerves, that he always found

" I preſently afterwards conſidered, that the *formation* of the " bubbles of air at the green matter was no proof that they " were *yielded* by it; ſince no air, or even vapour, can iſſue " from water, but at the place where it is bounded by ſome " other ſubſtance; and the water might yield its air con- " tiguous to one kind of ſubſtance in preference to another. " Though, therefore, I had not perceived any bubble of air " to iſſue from the water that had depoſited it, or from any " part of the tranſparent glaſs, but only, as it ſeemed, from " the green matter, I had been too haſty in concluding even " that the water could not yield the air but with the aſſiſt- " ance of that ſubſtance. At length the following experi- " ment gave me juſt ideas on the ſubject:

" Obſerving one of my phials of water, that had got a " coating of the green matter, yielding air very copiouſly, I " poured the water out of it into a clean phial, and found " that, by the agitation given to it in the act of decanting,

found it, in caſe the water was expoſed to the *light*; and when the water, being kept in the dark for ſome time, had depoſited a whitiſh filmy matter, it has become green after a few days expoſure to the ſun. That although he obſerved that river and rain-water, after long ſtanding, depoſited ſome of that green matter, yet the pump-water that he uſed, depoſited it much more freely, eſpecially when it had been impregnated with fixed air. And laſtly, that this green matter is formed alſo in veſſels that are kept cloſe ſtopped; on which account this matter ſeems to be ſomething different from animal or vegetable bodies.

This ſubſtance, which is at firſt green, becomes gradually of a yellow, or rather orange-colour, and, when viewed through a microſcope, it ſeems to be a congeries of compact earthy matter, with a few hollow filaments and very few globular parts.

" it ſparkled as much as any Pyrmont or Seltzer water. " Inverting it in a baſin of water, I collected the air, and " found it to be very pure. I treated ſeveral other phials in " the ſame manner, and, the ſubſequent appearances being " the ſame, I had no doubt but that, when water is brought " into a ſtate proper for depoſiting that green matter, it is, " by the ſame proceſs, prepared for the ſpontaneous emiſſion " of a conſiderable quantity of pure air *." III. Laſtly, it appears from the experiments of Dr. PRIESTLEY and others, that the permanently elaſtic fluid contained in pump-water is different at different times, as well as in different places; but, ſays Dr. PRIESTLEY, " the general concluſion I have " drawn from the whole, that I was able to obſerve, is, that " whatever air is naturally contained in water, as calcareous " matter, &c. becomes, after long ſtanding, but eſpecially " when expoſed to the ſun, *depurated*, ſo as at length to become " abſolutely dephlogiſticated; and that this air, being " continually emitted by all water expoſed to the action of " the ſun's rays, muſt contribute to the melioration of the " ſtate of the atmoſphere in general *."

It has been aſcertained by Dr. M. DOBSON, of Liverpool, that the ſea-water contains dephlogiſticated air, or air certainly purer than common air; which may be extracted from it by boiling in glaſs veſſels. The bulk of the air that can, by this means, be obtained, is to the bulk of the ſea-water as one to ſixty, nearly.

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* Exper. and Obſer. vol. iv. ſect. xxxiii.

Having mentioned the principal and more general obſervations relating to the production of dephlogiſticated air, it is now neceſſary to examine the nature of that elaſtic fluid, and alſo various other particulars relating to the origin of it; which particulars it was not deemed proper to inſert among the preceding obſervations, ſince they had an immediate connection with the ſubject we are now going to examine, viz. the nature of that permanently elaſtic fluid.

From a variety of experiments and conſiderations, Dr. PRIESTLEY was led to conſider dephlogiſticated air as a compound of nitrous acid and earth. Indeed, if it be conſidered that by means of heat, nitre may be intirely deprived of its acid part; that the produce ariſing from this decompoſition is principally, if not wholly, dephlogiſticated air; and that this dephlogiſticated air, not ſhewing any marks of acidity, muſt, according to the general laws of chymiſtry, contain that acid enveloped in ſome other ſubſtance, like ſulphur, (which contains a great quantity of vitriolic acid without ſhewing any marks of acidity, becauſe the other components of that ſubſtance keep that acid in a ſtate of concealment:) and if it be alſo conſidered, that nitre is formed only in the open air; one is naturally led to conſider the dephlogiſticated air to be a compound of nitrous acid and ſomething elſe, which may, very likely, be an earth. But, beſides theſe conſiderations, Dr. PRIESTLEY eſtabliſhes his theory upon very remarkable experiments, the principal of which are thoſe in which, by repeated additions of freſh nitrous acid upon the very ſame earthy ſubſtance which had yielded dephlogiſticated air, and by expoſing it again and again to a ſufficient degree of heat in proper veſſels, more and more dephlogiſticated air may be obtained from it, until the whole of that earthy ſubſtance is exhauſted. It is a remarkable fact, that when dephlogiſticated air is produced by giving to the materials a violent degree of heat, its appearance is generally turbid, owing to ſome whitiſh powder, and probably to ſome vapour alſo, that is ſuſpended in it, and which powder is depoſited according as the dephlogiſticated air cools [*]. Upon this Dr. PRIESTLEY remarks, that as a "conſiderable quantity of earth is actually contained in it "when hot, and depoſited when it is cold, it ſhould ſeem "that it muſt retain ſome proportion of earth in the com- "mon temperature of the atmoſphere [§]."

Notwithſtanding the conviction with which thoſe experiments and obſervations of Dr. PRIESTLEY ſeem to be attended, his theory has been ably controverted by Mr. FONTANA. This accurate and learned philoſopher obſerves, that when dephlogiſticated air is extracted from red precipitate by heat, the mercury which is revivified in the operation weighs nearly as much as the mercury that was employed in making that quantity of red precipitate. Mr. LAVOISIER having reduced two ounces one drachm of mercury into red pecipitate, and having afterwards revivified it, loſt a very few grains of the mercury, which might be the weight of a little red matter that was found adhering to the neck of the veſſel. Mr. FONTANA having repeated this experiment ſeveral times, the loſs of weight was often leſs than a grain. The veſſel he uſed had a neck about two feet long, and he particularly remarks, that, in order to ſucceed in this experiment, the fire ſhould be managed with very great dexterity; for if that is too ſtrong, part of the precipitate will be volatilized, and then the reſult of the experiment is precarious.—Upon this Mr. FONTANA juſtly obſerves, that the dephlogiſticated air is produced from the acid employed in making the precipitate, and that, conſequently, no earth enters into its compoſition*. Dr. PRIESTLEY, in conſequence of thoſe obſervations of Mr. FONTANA, repeated, ſeveral times, the above-mentioned experiment with red precipitate, and finds, contrary to Mr. FONTANA, that they were always attended with a conſiderable loſs of the weight of the mercury. In one of his experiments, out of 11 dwts. 10 grs. of mercury, 1 dwt. 2 grs. were loſt. In another experiment, 88 grs. were loſt, out of a quantity of red precipitate, in which half an ounce of mercury had been employed. In ſhort, the weight of mercury loſt in his experiments, or rather the proportion of it to the weight of the mercury employed, was always various, and the difference being not very ſmall *. It appears, alſo, that the Doctor employed a ſtrong degree of heat in thoſe experiments, which, no doubt, volatilized part of the precipitate, and, expelling it from the retort, occaſioned the loſs of weight. That this muſt have been the caſe ſeems evident, even by conſidering the whitiſh powder that gives the turbid appearance to the dephlogiſticated air, when produced by employing a violent fire, and which is depoſited immediately after the production of the air. So that we may conclude, that no experiment hitherto made, deciſively ſhews that any earth enters into the compoſition of dephlogiſticated air, and that the contrary ſeems to be very probable; ſince the dephlogiſticated air has been produced by Mr. SCHEELE from the nitrous acid alone; ſince, in the reduction of red precipitate, no earth of the metal is loſt; and ſince dephlogiſticated air can be produced from all the earths, with the addition of nitrous acid, in which caſe, ſuppoſing that an earth is neceſſary for the formation of dephlogiſticated air, it would follow, that either every kind of earth can ſerve that purpoſe, or that all the various diſtinctions of earths, viz. metallic, calcareous, ſiliceous, &c. are ultimately the ſame, which ſeems unlikely on various accounts.

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[*] "I have frequently obſerved, that when the production of dephlogiſticated air "is very copious, it is ſurcharged with a great quantity of white powdery matter. "I once collected a quantity of this ſubſtance, and found that it continued in "the form of a white powder; it made no effervеſcence with ſpirit of nitre, but "ſeemed to be in part, though not wholly, diſſolved in it." Exper. and Obſer. vol. iii. p. 91.

[§] See the preface to the 3d vol. of Exper. and Obſer.

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* Recherches Phyſiques ſur l'Air dephlogiſtiqué.

Here it is not meant to aſſert, that no earthy particles at all can be ſuſpended in dephlogiſticated air, for that is very

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[*] See the preface to the third vol. of Exper. and Obſer.

probable ; but it is only advanced, that theſe earthy particles are accidental and foreign to its conſtitution. In ſhort, that dephlogiſticated air can exiſt, and does generally exiſt, without containing any earth. At leaſt, we have no evident reaſon to ſuſpect the contrary.

It is true, that we cannot account for the exiſtence of an acid, viz. the nitrous, in dephlogiſticated air, without giving any ſigns of acidity, or without ſomething elſe being combined with it; but this only requires farther inveſtigation, and does by no means warrant an aſſertion, which is contrary to many deciſive experiments. It may even be ſuppoſed, that dephlogiſticated air is a ſingle homogeneous ſubſtance, and that by the acceſſion of ſomething elſe it becomes nitrous acid, rather than ſuppoſing the nitrous acid to be a ſimple ſubſtance, and dephlogiſticated air a compound body. Mr. FONTANA is of opinion, that the nitrous acid is a compound of dephlogiſticated air and phlogiſton * ; ſo that when the nitrous acid is added to ſubſtances which contain no phlogiſton, in order to obtain dephlogiſticated air, the nitrous acid is decompoſed, its phlogiſton combines with the ſubſtance employed, and the dephlogiſticated air acquires its elaſtic form.—If we conſider, that by the addition of the phlogiſton of nitrous air, a quantity of dephlogiſticated air may be diminiſhed almoſt to nothing, we cannot entertain any difficulty in conceiving that it may be concentrated, ſo as to

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* Journal de Phyſique par 1778. Experiences ſur l'Alkali, &c. par Mr. l'Abbé FONTANA.

form a viſible fluid when combined with phlogiſton and water. This ſuppoſition, viz. that the nitrous acid is a compound of dephlogiſticated air and phlogiſton, affords an explanation of the reduction of certain metallic calxes without addition, as of the calx of lead and of mercury, made by diſſolving thoſe metals. Mr. FONTANA explains it in the following manner:—The nitrous acid, when added to thoſe metals, deprives them of their phlogiſton, and with it forms nitrous air. But the metallic calxes are then combined with part of the nitrous acid, and if the action of fire upon them is ſufficiently ſtrong and continued, they will decompoſe that nitrous acid which is combined with them, ſo that the phlogiſton of it joining with the calx, the dephlogiſticated air aſſumes its elaſtic form, and the metallic calx is revivified *.

As for the phenomena exhibited by the precipitate per ſe, it may be, that by long expoſure to the atmoſphere, in the degree of heat that is neceſſary for the formation of that ſubſtance, it acquires from the atmoſphere both the phlogiſton and the dephlogiſticated air, which may form a nitrous acid, &c.—Notwithſtanding, it muſt be confeſſed that we are, as yet, much in the dark reſpecting the nature of precipitate per ſe.

There is a phenomenon obſervable in the production of dephlogiſticated air, which does not appear to be ſatisfactorily explained by any theory hitherto publiſhed. It is the irregularity of the purity of the air produced. A remarkable

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* Recherches Phyſiques ſur la nature de l'air dephlogiſtiqué

fact of this kind is obſervable with common lime, which, when mixed with nitrous acid, and expoſed to a proper degree of heat, gives firſt dephlogiſticated air, then yields air nearly of the goodneſs of common air, and laſtly again dephlogiſticated air. Mr. FONTANA mentions, that if the lime has been ſlacked in the air, it yields firſt dephlogiſticated and then nitrous air; and if the lime has been ſlacked in water, it will yield dephlogiſticated air only. He alſo ſays to have met with ſtill greater irregularities in the courſe of his experiments on animal and vegetable ſubſtances; but that the metallic bodies ſeem to follow the general laws with more regularity [*].

Dr. PRIESTLEY has obſerved, that pipe-clay, mixed with nitrous acid, produces firſt fixed air, then common air, next nitrous air, then dephlogiſticated air, and laſtly phlogiſticated air. This phenomenon of the production of phlogiſticated, after the dephlogiſticated air, Mr. FONTANA conſiders as a proof of his theory, viz. that nitrous acid conſiſts of dephlogiſticated air and phlogiſton, and that, when the former is produced, the latter is communicated to the ſubſtance employed; for, ſays he, in this experiment of Dr. PRIESTLEY, the nitrous acid that is decompoſed during the production of dephlogiſticated air, depoſits its phlogiſton upon the clay, but when the clay cannot abſorb any more phlogiſton, then the next dephlogiſticated air that is produced, abſorbs that phlogiſton, and becomes phlogiſticated*. But I own that, according to Mr. FONTANA's theory, I cannot conceive how, in this experiment, the nitrous acid could be decompoſed, when the calcareous earth is no longer capable of abſorbing its phlogiſton. This obſervation is alſo applicable to Mr. SCHEELE's experiment of producing dephlogiſticated air out of nitrous acid alone.

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[*] Recherches Phyſiques ſur l'air dephlogiſtiqué.

In regard to the properties of dephlogiſticated air, it may be ſaid in general, that it has all the properties of common air, but in a more eminent degree, viz. it aſſiſts animal reſpiration and combuſtion, not only better, but conſiderably longer than an equal quantity of common air; it is diminiſhed by nitrous air, and by phlogiſtic proceſſes, much more than common air is, &c.: but, as this rule is not quite general, viz. applicable to every one of their properties, and as the variety of phenomena are not only ſtriking to the obſerver, but particularly intereſting, it is neceſſary to take notice of ſeveral of them ſingly.

This fluid, permanently elaſtic and inviſible, like common air, has been found to be ſpecifically heavier than common air; though the difference is not great. Dr. PRIESTLEY finds its ſpecific gravity to be to that of common air as 187 to 185†; and, according to Mr. FONTANA, as 160 to 152‡.

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* Recherches Phyſiques ſur l'air dephlogiſtiqué.

† Exper. and Obſer. p. 94.

‡ The methods uſed by Dr. PRIESTLEY and by Mr. FONTANA have been deſcribed in the preceding Chapter.

When dephlogiſticated air is to be weighed, care ſhould be had firſt to free it very accurately from any mixture of fixed air.

When a lighted candle is introduced into a phial containing dephlogiſticated air, its flame not only grows larger, but becomes exceedingly bright. When the dephlogiſticated air is very pure, the candle burns with a crackling noiſe, as if the air contained ſome combuſtible matter, and waſtes the wax or tallow ſurpriſingly faſt. The heat of the flame is alſo very intenſe. But the beſt method to obſerve its intenſity is the following:—Fill a bladder with dephlogiſticated air, then faſten a glaſs tube to the neck of the bladder. The outward aperture of this tube muſt be drawn to a fine point, like that of an ordinary blow-pipe. Then holding the extremity of the tube near the flame of a large candle, or of a lamp, preſs the bladder, ſo as to force the dephlogiſticated air out through the ſmall aperture of the tube, which will drive the flame of the candle into an horizontal direction, augmenting its force prodigiouſly; ſo that if ſmall bits of any metal held upon a piece of charcoal, or upon a piece of a broken crucible, be preſented to the apex of that flame, they are preſently melted. Even grains of platina are melted by theſe means. "Nothing," *ſays Dr.* PRIESTLEY, "would "be eaſier than to augment the force of fire to a prodigious "degree, by blowing it with dephlogiſticated air inſtead of "common air. This I have tried, in preſence of my friend "Mr. MAGELLAN, by filling a bladder with it, and puffing "it, through a ſmall glaſs-tube, upon a piece of lighted

" wood; but it would be very eaſy to ſupply a pair of " bellows with it from a large reſervoir.

" Poſſibly much greater things might be effected by " chymiſts, in a variety of reſpects, with the prodigious heat " which this air may be the means of affording them *."

When dephlogiſticated air is mixed with inflammable air, and the flame of a candle is approached to the mixture, or an electric ſpark is ſent through it; the inflammable air explodes with a much greater report than when it is mixed with common inſtead of dephlogiſticated air. If an ounce glaſs phial (which for this experiment ſhould be very ſtrong) is filled with a little more than one third of dephlogiſticated and the reſt inflammable air, and the flame of a candle is preſented to its mouth, it will explode nearly as loud as a ſmall piſtol, the report being incomparably greater than when the ſame phial is filled with common and inflammable air in the beſt proportion.

It is very clear that dephlogiſticated air muſt promote all phlogiſtic proceſſes much better than common air, ſince they all depend upon the very ſame principle, namely, the ſuperior power of this ſort of elaſtic fluid to imbibe the inflammable principle. " I put," *ſays Dr.* PRIESTLEY, " a quantity of " Mr. BEWLY's pyrophorus into one of the ſmall jars † which I uſe

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* Exper. and Obſer. vol. ii. p. 100.

† Mr. BEWLY prepares this pyrophorus in the following manner:—" I fill," *ſays he*, " half or three fourths of the bowl of a tobacco-pipe with a mixture, " conſiſting of two parts of alum, previouſly calcined in a red-heat, and of " powdered charcoal and ſalt of tartar each one part; preſſing the matter down " ſlightly

" I uſe for experiments on air in quickſilver; then, filling up " the veſſel with quickſilver, I inverted it in a baſin of the " ſame, and threw up dephlogiſticated air at different times. " It always occaſioned a ſudden and vehement accenſion, like " the flaſhing of gunpowder, and the air was greatly di- " miniſhed, as might have been foreſeen *."

As the dephlogiſticated air aſſiſts all phlogiſtic proceſſes much better, ſo it is thereby much more diminiſhed than common air. Indeed ſometimes it is reduced into ſo ſmall a ſpace, that is really ſurpriſing. When the dephlogiſticated air is very pure, if to two meaſures of it be added two meaſures of nitrous air, the whole of this mixture, viz. all the four meaſures, will be reduced into a ſpace equal to about one meaſure; which conſiſts of fixed air and phlogiſticated air.

" ſlightly, and filling the remainder of the bowl with fine ſand. As ſoon as the " powder becomes hot, the ſand lying over it is put into a ſtate of ebullition, " which generally continues ſeveral minutes. This appearance ſeems to pro- " ceed partly from the vitriolic acid in the alum leaving its earth, and expelling " *fixed air* from the alkali; while another part of it is poſſibly converted into " *vitriolic acid air*. This phenomenon is ſucceeded by the appearance of a " blue ſulphureous flame, proceeding from the combination of the ſame acid " with the *phlogiſton* of the coal, and which continues about ten minutes or a " quarter of an hour. After it ceaſes, no other remarkable appearance preſents " itſelf. The matter is now to be kept in a red-heat twenty minutes or half an " hour; or it may continue there two hours longer, if the operator pleaſes, with- " out any injury to the pyrophorus. The pipe being taken out of the fire, the " matter is knocked out of it as ſoon as it becomes cool, and generally, pretty " ſoon afterwards, takes fire ſpontaneouſly." See the Appendix to the 3d vol. of Exper. and Obſer.

* Exper. and Obſer. vol. iv. p. 261.

The quantity of fixed air, produced by the diminution of dephlogiſticated with nitrous air, is greater than that produced when common air is diminiſhed by nitrous air. The phlogiſticated air ariſing from dephlogiſticated air diminiſhed by nitrous air, when ſeparated from the fixed air (like that ariſing from the diminution of common with nitrous air) is ſpecifically lighter than common air, and conſequently than dephlogiſticated air.

In order to form a juſt idea of the comparative purity between dephlogiſticated and common air, the reader muſt recollect, that if nitrous air be gradually added to common air, the whole will be diminiſhed, but the diminution will be greateſt at firſt, and will afterwards gradually diminiſh till it vaniſhes. Thus, for inſtance, if to two meaſures of common air half a meaſure of nitrous air be added, the whole will be diminiſhed into about 1½ meaſure; ſo that out of 2½ of elaſtic fluid, one meaſure has been loſt; and if to this mixt and diminiſhed quantity another half meaſure of nitrous air be added, the original three meaſures of elaſtic fluid will be reduced to about two meaſures, which is equal to the quantity of common air uſed; ſo that this quantity of common air has taken up two half meaſures, viz. a quantity equal to half its bulk of nitrous air, before the whole mixt and diminiſhed quantity amounted to its own original bulk. Now, if a quantity of another ſpecimen of reſpirable air takes up an equal quantity of nitrous air, before the whole diminiſhed quantity occupies a ſpace equal to that occupied by the reſpirable air, before it was mixed with the nitrous air, then this air is conſidered to be twice as good as common air, becauſe this ſpecimen of reſpirable elaſtic fluid requires twice as much nitrous air as common air does, in order to fill up its original ſpace. If a ſpecimen of air requires three times as much nitrous air as common air does, before it makes up the bulk it had before, then it is ſaid that this air is thrice as good as common air. Thus, ſuppoſe that by the taſte of nitrous air, after the manner deſcribed in the VIth Chapter of the preceding Part, common air at a mean gives II, I, 2. and a ſpecimen of dephlogiſticated air gives II, I, 1,5. II, II, 1,8. II, III, 2. then it is ſaid that the latter is three times as good as the former.

Here it is not meant, that if more nitrous air is afterwards added to thoſe ſpecies of air, no farther diminution will ariſe; but only, that in this caſe the whole bulk of reſpirable and nitrous air would amount to more than the original bulk of the reſpirable air only.

Although the name of dephlogiſticated air has been given to all ſorts of elaſtic fluid, which aſſiſt reſpiration and the other phlogiſtic proceſſes better than common air, yet the reader muſt have obſerved, that ſome ſpecimens of dephlogiſticated air are much purer than others, and that the difference among ſome of them is very great; hence the effects of this permanently elaſtic fluid are ſubject to great variation, and muſt be alway eſtimated from the degree of purity of the dephlogiſticated air employed. The purity of the dephlogiſticated air that is commonly obtained in the greateſt number of the proceſſes mentioned above, is moſtly ſuch, that when one meaſure of it is mixed with two meaſures of nitrous air, the whole takes up the ſpace of about three quarters of a meaſure; but in conducting ſeveral of thoſe experiments, eſpecially in obtaining dephlogiſticated air from nitre, if care be had to uſe proper clean veſſels, wherein nothing containing phlogiſton might be ſuſpected, &c. the air obtained is much purer, eſpecially that produced in ſome period of the proceſs *. The pureſt air that, as far as I know, has been hitherto obtained, is that mentioned by Dr. PRIESTLEY, in his 4th vol. of Exper. and Obſer. ſect. xxv. It was produced by a ſolution of mercury in ſpirit of nitre, diſtilled with a glaſs retort in a ſand-heat †. This dephlogiſticated air was ſo pure, that one meaſure of it being mixed with two meaſures of ſome nitrous air, that had been produced in the firſt part of the ſame proceſs, the whole, after the diminution was over, occupied the ſpace of three hundredth parts of a meaſure. "Repeating," *ſays he*, "the "experiment, I found that two meaſures of nitrous air were "rather more than ſufficient to ſaturate one meaſure of the de-

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* The turbid or clear appearance of the dephlogiſticated air, when juſt produced, in different periods of the ſame proceſs, is no ſure ſign of its purity; ſince ſometimes the more turbid, and ſometimes the moſt tranſparent, is the pureſt.

† The Doctor remarks, that this ſolution had been kept for ſeveral months in a phial with a ground ſtopper.

“ phlogiſticated air; ſo that, poſſibly, had the former ex-
“ periment been made with more circumſpection, the dimi-
“ nution, extraordinary as it was, would have been ſomewhat
“ greater. Indeed it cannot be ſuppoſed, that *exactly* two
“ meaſures of nitrous air ſhould be the preciſe quantity that
“ would produce the greateſt diminution. It ſhould alſo be
“ conſidered, that a ſmall portion of air might be yielded by
“ the water in which the experiment was made.

“ Upon the whole, therefore, I am inclined to think, that,
“ were it poſſible to make both the nitrous and dephlogiſti-
“ cated air in the greateſt purity, and then to mix them in
“ ſome exact proportion, the aerial form of them both would
“ be entirely deſtroyed, the whole quantity ſeeming to diſ-
“ appear, as in the mixture of alkaline and acid air. But
“ whereas a white ſaline ſubſtance is the immediate viſible
“ reſult of this mixture, there is no viſible produce from
“ the other, the whole, whatever it be, being diſſolved in
“ the water.

When dephlogiſticated air is kept in contact with ſubſtances that contain phlogiſton, and do eaſily part with that principle, it loſes its degree of purity in a very ſhort time. Dr. Priestley having introduced a conſiderable quantity of very dry clean nails into a receiver full of dephlogiſticated air, and inverted in quickſilver, found that, about nine months after, one tenth of the whole quantity of air had diſappeared, though he could not perceive any ruſt upon the nails; which ſhews that pure air has ſuch an affinity with phlogiſton as to deprive ſome metals of it very eaſily.

In the preceding pages we took notice of the dephlogiſticated air obtained from water, and likewiſe obſerved, that by means of diſtilled or boiled water, common air may be changed into dephlogiſticated air, or rather, the pureſt part of it may be ſeparated from that which is more impure. But here it is neceſſary to mention ſome other particulars relating to the effects of water on dephlogiſticated air, which, in general, are not like thoſe produced by water on common air. Dr. PRIESTLEY having once made a large reſervoir of dephlogiſticated air, found that by ſtanding in pure water for about ten days, from being 4½, it had become 5½ better than common air [*]. In another place, Dr. PRIESTLEY mentions, that having let ſome boiled water imbibe a quantity of dephlogiſticated air, and about a fortnight after having expelled the dephlogiſticated air from the ſaid water, found it a little improved [†].

Mr. FONTANA aſſerts, that water in general abſorbs about twice as much of dephlogiſticated as of common air. “ Accordingly,” *ſays he*, “ I have found that the water of the “ Seine, at Paris, after it has been boiled for a long time, “ abſorbs in forty days about one fourteenth of its own bulk “ of dephlogiſticated air, when in the ſame length of time it

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[*] Exper. and Oſerv. vol. ii. p. 96.

[†] Ibid. vol. iv. p. 353.

"does not abſorb more than one twenty-eighth of common "air *."

Mr. FONTANA has alſo obſerved a remarkable difference between the reſults ariſing from the agitation of common air in water, and of dephlogiſticated air in water; the former being by that means generally increaſed in bulk till a certain degree, and afterwards diminiſhed; whereas the latter begins to be diminiſhed even from the very beginning of the operation. "This laſt-mentioned property," *ſays he*, "of "the dephlogiſticated air ſeems to ſhew, that this is a fluid "much different from common air, becauſe it has its peculiar "properties, by which it differs from common air, not from "*more* to *leſs* only, but intirely; as is ſhewn by the property "this fluid has of being abſorbed by water; whereas com"mon air receives an increaſe of bulk and elaſticity by "being ſhaken in water †."

The greateſt uſe to which this dephlogiſticated air might be applied, is for diſeaſes of the lungs; which are juſtly reckoned among the moſt ſtubborn diſeaſes that afflict mankind. Perſons affected with thoſe diſorders are often conveyed into diſtant places, in ſpite of any trouble and expence, for the ſake of breathing a kind of air, which at moſt is very little better than the air of their actual dwelling-place; whereas, by uſing this artificial air, they might ſave the manifold inconveniences of travelling, &c. and would breathe an elaſtic fluid incomparably better than the air of any country upon earth. From the unanimous obſervations of thoſe philoſophers, who have breathed dephlogiſticated air for curioſity's ſake, it appears that the feeling of this elaſtic fluid to the lungs was not ſenſibly different from that of common air, but that they all felt, or at leaſt fancied to have felt, their breaſts peculiarly eaſy and light for ſome time after the experiment. "From the greater ſtrength," *ſays Dr.* PRIESTLEY, "and vivacity of the flame of a candle, in this "pure air, it may be conjectured, that it might be peculiarly "ſalutary to the lungs in certain morbid caſes, when the "common air would not be ſufficient to carry off the phlo-"giſtic putrid effluvium faſt enough. But, perhaps, we "may alſo infer from theſe experiments, that though pure "dephlogiſticated air might be very uſeful as a *medicine*, it "might not be ſo proper for us in the uſual healthy ſtate of "the body: for, as a candle burns out much faſter in de-"phlogiſticated than in common air, ſo we might, as may "be ſaid, *live out too faſt*, and the animal powers be too ſoon "exhauſted in this pure kind of air *."

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* Phil. Tranſ. vol. lxix. p. 439.

† Ibid. p. 444.

The greateſt objection relating to the uſe of dephlogiſticated air in phyſical caſes, is the difficulty of obtaining a conſiderable quantity of it, and the want of an eaſy method of adminiſtering it. But this objection, great as it may ſeem, will be found to be not unſurmountable; and in the following pages it will appear, that the procuring and adminiſtering this pure reſpirable air is far from being impracticable, and requires no great expences. I beg here, therefore, the reader's attentive conſideration, this being an intereſting ſubject.

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* Exper. and Obſer. vol. ii. p. 101.

The cheapeſt known way to get a large quantity of dephlogiſticated air, is by means of nitre. The price of this ſalt, in London, is at preſent eighteen pence *per* pound; and by heat only, it yields dephlogiſticated air at the rate of ſeven or eight hundred cubic inches *per* ounce, or, at a medium, 12,000 cubic inches *per* pound.

Suppoſing that the dephlogiſticated air obtained from nitre is four times purer than common air, it follows that an animal can breathe it four times as long as an equal quantity of common air; which ſuppoſition, as appears from actual experiments, is rather leſs than above the uſual reſult; ſome animals having lived ſix, and even more, times longer in dephlogiſticated air, extracted from nitre, than in an equal quantity of common air.

It has already been obſerved, that by the act of reſpiration, a quantity of fixed air is formed (whether it originates from the body, or from a combination of the phlogiſton with the reſpirable air, or otherwiſe) and the air in which an animal is confined, becomes noxious principally becauſe ſome fixed air is formed and mixed with it; ſo that if, by means of lime-water, that fixed air be ſeparated from it as ſoon as it is formed, the animal would live longer in it than otherwiſe. Now Mr. FONTANA has found (as is related by Dr. INGENHOUSZ [*], and as I remember myſelf to have heard him ſay) that an animal confined in a quantity of dephlogiſticated air, will live about thirty times longer in it, when the receiver, containing the dephlogiſticated air, *ſtands in lime-water*, than when it ſtands in common water, becauſe the lime-water abſorbs the fixed air very readily.

A man makes in general about fifteen inſpirations in a minute, and takes in about thirty cubic inches of air. But the air that has been once inſpired is not thereby much injured, and it may be inſpired again and again; ſo that upon a very moderate calculation, and as appears from actual experiments often repeated, we may ſafely aſſert, that a perſon can breathe 400 cubic inches of good ordinary atmoſpheric air at leaſt thirty times, without the leaſt inconvenience, *i. e.* it would ſerve for two minutes; after which, that air, though much depraved, is ſtill in a ſtate of being breathed, but then it would begin to occaſion ſome uneaſineſs. Now, according to the ſuppoſition mentioned above, an animal can breathe dephlogiſticated air four times as long as an equal quantity of common air; therefore 400 cubic inches of dephlogiſticated air can ſerve at leaſt for 120 inſpirations, or for eight minutes. But, according to Mr. FONTANA, when the dephlogiſticated air is in contact with lime-water, it will ſerve thirty times as long as otherwiſe; therefore in this caſe

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[*] Experiments on Vegetables—Pref. p. 48.

400 cubic inches of dephlogiſticated air may be breathed for four hours, and 12,000 cubic inches of that elaſtic fluid, which is the quantity ordinarily obtained from one pound of nitre, may be breathed for 120 hours. But, upon the ſuppoſition that thirty cubic inches of common air, taken into the lungs in an ordinary inſpiration, are compleatly phlogiſticated by a ſingle inſpiration, ſo as not to be uſeful afterwards; and alſo ſuppoſing, that by the contact of lime-water, dephlogiſticated air is rendered capable of being breathed only ten times longer than otherwiſe; the calculation would be as follows:—27,000 cubic inches of common air are neceſſary to one perſon for one hour; therefore the ſame quantity of dephlogiſticated air will ſerve to the ſame perſon for four hours, when not in contact with lime-water, but by uſing the lime-water, it will ſerve forty hours. Conſequently, 12,000 cubic inches of dephlogiſticated air (or the produce of one pound of nitre) will ſerve to one perſon for eighteen hours, nearly. So that by employing one pound of nitre, a perſon may have dephlogiſticated air for more than one day, ſince it can hardly be ſuppoſed that he would breathe it in the time of ſleep. Perhaps the uſe of this pure air for a ſhort time, for inſtance, one or two hours every day, or even leſs, may be of great uſe, and may even be thought ſufficient for ſome diſeaſes *.

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* "It is pleaſing, however, to obſerve, how readily and perfectly dephlogiſti- "cated air mixes with phlogiſticated air, or air injured by reſpiration, putre- faction,

I do not know that any fair trial has been hitherto made of this application, in caſe of diſeaſes of the lungs. It ſeems to be a very promiſing remedy; but, as the philoſophical properties of reſpirable air in general, and the effects of reſpiration on it, have been already mentioned, I ſhall leave the farther conſideration of it to phyſicians, and ſhall paſs to deſcribe the practical eaſy method of producing and adminiſtering this ſort of permanently elaſtic fluid.

The inſtruments neceſſary for the production of dephlogiſticated air from nitre, are the following; *viz.* Earthen retorts,

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"faction, &c. each tempering the other; ſo that the purity of the mixture may "be accurately known from the quantity and quality of the two kinds of air "before mixture. Thus, if one meaſure of perfectly noxious air be put to one "meaſure of air that is exactly twice as good as common air, the mixture will "be preciſely of the ſtandard of common air.

"I obſerved alſo, in making this experiment, that after mixing one meaſure "of each of theſe kinds of air, they made exactly two meaſures; ſo that there "was neither any increaſe nor diminution of quantity in conſequence of the "mixture, as is the effect of mixing nitrous air with either common or de-"phlogiſticated air.

"It may hence be inferred, that a quantity of very pure air would agreeably "qualify the noxious air of a room in which much company ſhould be confin-"ed, and which ſhould be ſo ſituated, that it could not be conveniently ven-"tilated; ſo that from being offenſive and unwholeſome, it would almoſt in-"ſtantly become ſweet and wholeſome. This air might be brought into the "room in caſks, or a laboratory might be conſtructed for generating the air, "and throwing it into the room, as faſt as it ſhould be produced." PRIESTLEY's Exper. and Obſer. vol. ii. p. 97.

For this purpoſe of purifying the unventilated air of a room, one or more tubs of lime-water might alſo be added.

torts, or earthen veſſels with a ſtreight neck, ſomewhat in the ſhape of Florence flaſks, but with a longer neck; theſe being cheaper than the retorts, and anſwering as well:—A ſmall furnace, in which the earthen retort muſt be kept red hot. A common chimney fire is not ſufficient. Theſe furnaces may be very eaſily made out of large black-lead crucibles.—The nitre muſt be put into the retort, or other veſſel, ſo as to fill half, or nearly three quarters of its belly; then a bent glaſs tube is luted to the neck of the earthen veſſel, in ſuch manner as not to let any elaſtic fluid eſcape into the open air. The beſt lute, or cement, for this and ſimilar purpoſes, is made by mixing together whiting and drying oil.—The retort being put into the furnace, muſt be ſurrounded with lighted charcoal, which muſt be ſupplied according as it waſtes: in ſhort, the belly of the retort muſt be kept quite red hot, or rather white hot, for about three hours at leaſt. If, inſtead of the retort, the other deſcribed earthen veſſel be uſed, care ſhould be had to place it with the neck as little inclined to the horizon as poſſible, leſt the nitre ſhould ſtop the neck of it, and break the veſſel. A tub of water, with a ſhelf as already deſcribed, being placed pretty near the furnace, the extremity of the glaſs tube, that is cemented to the retort, muſt be immerſed into the water of the tub, ſo that the dephlogiſticated air that eſcapes from it may be received into large glaſs jars, filled with and inverted in the water of the tub.

The retort, or other earthen veſſel that is uſed for this purpoſe, cannot ſerve for more than once, becauſe it generally breaks in cooling, and beſides, the decompoſed nitre cannot be eaſily taken out of it. The retort capable of holding a pound of nitre for this operation, coſts at leaſt half-a-crown; the other earthen veſſels, in the ſhape of Florence flaſks, but with longer necks, coſt about eighteen pence apiece, or two ſhillings; ſo that the price of theſe veſſels forms a conſiderable part of the expence. If glaſs veſſels are employed, the nitre will not yield near ſo much air, though of a purer ſort, becauſe the glaſs veſſels cannot endure ſo great a fire as the earthen ones. The retorts of metal, or at leaſt of thoſe metals which are uſually employed for ſuch purpoſes, as iron and copper, phlogiſticate, in great meaſure, the dephlogiſticated air as ſoon as it is produced. So that earthen veſſels are, upon the whole, the moſt proper for this purpoſe. Conſidering, then, all theſe circumſtances, it appears that when a perſon has the uſual apparatus and furnace, the expences at preſent neceſſary in London for the production of 12,000 cubic inches of dephlogiſticated air (viz. the price of one pound of nitre, of an earthen retort or other veſſel, and of charcoal) amount to about four ſhillings, or four ſhillings and ſix pence.

The moſt proper manner of uſing the dephlogiſticated air for reſpiration is the following:—A glaſs cylinder with two open necks, ſuch as are uſed for electrical machines, muſt be furniſhed with a leathern pipe of about two feet long, and one inch in diameter, terminating in a glaſs or ivory tube about three inches long, and half an inch in diameter. This leather pipe is tied very faſt to one of the necks of the glaſs cylinder; to the other neck a ſtring is faſtened, having a leaden weight of about one pound at its extremity. The length of this ſtring muſt be ſuch, as that when the cylinder full of air is put into the water of the tub, and the leaden weight is let down to the bottom of the tub, the neck of the cylinder, to which the ſtring is faſtened, might be kept about two inches below the ſurface of the water, and thus might be prevented riſing above it. The ſize of the cylindrical glaſs veſſel ſhould be capable of holding a quantity of dephlogiſticated air ſufficient for the purpoſe intended. It ſhould be at leaſt eight inches in diameter, and 12 or 14 inches long excluſive of the necks. It is better to have it too large than too ſmall, ſince a large one may contain any ſmall quantity of air, whereas a ſmall one cannot contain a large quantity of it.

A cylindrical glaſs veſſel, &c. being thus prepared, the leather pipe muſt be tied nearly in the middle with a ſtring, ſo as to cloſe its variety; then the veſſel being quite filled with water, and inverted into the tub, the dephlogiſticated air is thrown into it through that neck to which the ſtring with the leaden weight is tied, after the uſual manner. Care only ſhould be taken to leave one or two inches of water in the cylinder; that is, not to fill it quite with air. Then the cylinder, ready for uſe, may be left to ſwim in the water of the tub, without any fear of the air eſcaping from it, ſince the ſtring with the leaden weight keeps its aperture below the ſurface of the water. Two or three largiſh lumps of quick-lime muſt be introduced into this cylinder, which will abſorb the fixed air formed in the act of reſpiration. Now, in order to breathe the dephlogiſticated air, the patient, having firſt made a natural *expiration*, muſt hold in his mouth the glaſs or ivory tube faſtened to the end of the leather pipe, and immediately after the operator muſt untie the ſtring faſtened round the middle of the leather pipe, which will open the communication between the patient's lungs and the cavity of the cylinder, and he may then breathe the dephlogiſticated air, &c. In this operation, care ſhould be had to let no air in or out through the noſe. Some people can do this very eaſily; otherwiſe the patient muſt hold his noſtrils cloſe with his hand. If the operation is required to be intermitted, the operator muſt tie the ſtring round the leather pipe the moment before the patient removes his mouth from the glaſs or ivory tube. If during the operation the ſtate of the air within the receiver were required to be examined, a little of it, by bending the cylinder, may be introduced into a ſmall receiver, &c.

In caſe that nitre, or other neceſſary conveniences, could not be procured, the next advantageous method of extracting dephlogiſticated air, is by means of red-lead and oil of vitriol; but, as we have already obſerved, a very ſmall quantity of air can be obtained from thoſe materials, in compariſon to what may be procured from nitre.

To put the pieces of quick-lime into the cylinder, for the abſorbtion of the fixed air, anſwers much better than lime-water; becauſe, as ſoon as the firſt portion of lime, that is diſſolved by the water, is precipitated by its combination with fixed air, the water becomes capable to diſſolve more lime, ſo as in ſhort to preſerve a continual ſupply of lime-water, capable of abſorbing any quantity of fixed air that may be uſually formed by reſpiration.

Were the uſe of dephlogiſticated air to be found beneficial for ſome of the various fatal diſorders of the lungs, it would not be difficult to contrive methods of obtaining abundance of dephlogiſticated air, by decompoſing a great quantity of nitre, and of employing it in a more convenient way.

When an animal is confined in a quantity of dephlogiſticated air, and is kept therein till he dies, that air is not rendered ſo very bad but it will be ſtill capable of great diminution when mixed with nitrous air. This is a remarkable phenomenon, which ſeems to ſhew that dephlogiſticated air is ſomething different from pure common air, or that common air is originally different from dephlogiſticated air lowered by the addition of phlogiſton. The phenomenon is certainly very remarkable; and ſometimes a quantity of dephlogiſticated air, after having been breathed by an animal till he died, will appear by the nitrous taſte to be even better than common air. When the experiment is performed in lime-water, the air, after the death of the animal, as I am infomed, will not ſuffer ſo great a diminution by the mixture of nitrous air, as it would otherwiſe; but it is ſtill diminiſhed much more than common air is after that an animal is dead in it; which ſhews, that the death of the animal in dephlogiſticated air, is principally owing to the fixed air formed by the act of reſpiration. It may be ſaid, that the inflammable principle diſcharged through the lungs of an animal, being perhaps combined with ſome other principle, requires a longer time to incorporate with the dephlogiſticated air, than the phlogiſton of the nitrous air; but this is only an hypothetical explanation of the above-mentioned remarkable phenomenon, which requires many direct proofs.

I ſhall in this place take notice of another great uſe for which dephlogiſticated air may be employed, relating to reſpiration; namely, to enable perſons to deſcend into deep pits, and to enter various ſubterranean paſſages, in order to explore mines, &c. which, on account of the noxious air exiſting in them, are left unſearched. Several ſuch places are met with in almoſt every country; and eſpecially in Italy, and about vulcanos. — Now, if a large bladder, into which a ſolution of lime in water is introduced, be filled with dephlogiſticated air, and a ſmall wooden or glaſs pipe be adapted to its neck, a man may hold that pipe in his

mouth,

mouth, and may breathe the dephlogiſticated air; and thus equipped he may enter into thoſe ſubterranean places, amidſt the various elaſtic fluids contained in them.

A large bladder of dephlogiſticated air may thus ſerve him for above a quarter of an hour, which is a length of time ſufficient for various purpoſes; beſides, if longer time is required to be ſpent in thoſe ſubterranean places, a perſon may have two or more bladders of dephlogiſticated air with him, and may ſhift as ſoon as the air of one of them is contaminated. Without the neceſſity of any more complicated apparatus, the bladders full of dephlogiſticated air may be kept ſtopped, by putting corks into the glaſs or wooden pipes that are tied to their necks. — This air might alſo be uſed for diving-bells, &c.

In regard to the effects of dephlogiſticated air upon plants, we have already obſerved, that vegetables will not thrive well in it. Dr. PRIESTLEY, Mr. FONTANA, Mr. SCHEELE, Dr. INGENHOUSZ, and others, are all perſuaded of this truth; the reaſon of which ſeems almoſt demonſtratively proved to be, the want of phlogiſton in dephlogiſticated air, which plants abſorb, and which ſeems neceſſary for their vegetation and growth. This obſervation itſelf (independent of Dr. INGENHOUSZ's experiments) ſeems to be an argument favourable to Dr. PRIESTLEY's juſt ſuppoſition, that plants in general purify the atmoſphere. Amongſt the various experiments made by ſeveral ingenious perſons, reſpecting the growth of plants in dephlogiſticated air, I ſhall only relate one for the ſatisfaction of my readers, which is of Dr. Priestley; the others concurring to confirm the ſame thing.

" In order to compare the vegetation of plants in air, differ- " ing as much as poſſible with reſpect to phlogiſton, I took " three ſprigs of mint; and having put all the roots into " phials, containing the ſame pump-water, that had been " ſome time expoſed to the open air, I introduced one of them " into a jar of common air, another into one of dephlogiſti- " cated, and the third into air that had been phlogiſticated " with nitrous air ſeveral months before. It was in ſuch a " ſtate, that one meaſure of it, and one of nitrous air, occu- " pied the ſpace of 1,75 meaſures. This was done in April; " and, examining the plants on the 12th of May following, I " found that the plant in this phlogiſticated air had grown " remarkably well, much better than that in the common " air; whereas the plant in the dephlogiſticated air had a " very ſickly appearance.

" I examined theſe plants on the 26th of the ſame month, " when the appearance continued nearly the ſame. And " then, examining the ſtate of the air, I found that, though " the plant in phlogiſticated air had grown ſo well, the air " was not ſenſibly improved by it. The dephlogiſticated " air was injured, which I attributed to the rotting of ſome

" of the leaves of the plant. The common air I did not at-
" tend to *."

The diſcovery of dephlogiſticated air, beſides the immediate uſe of that wonderful permanently elaſtic fluid, affords the explanation of various phenomena, which before had originated ſeveral improbable and unintelligible conjectures. The exiſtence of ſubterraneous fire may be explained very eaſily in the preſent ſtate of knowledge relating to dephlogiſticated air; ſince we may eaſily imagine, that much dephlogiſticated air being detached from ſeveral bodies within the bowels of the earth, by means of heat, it will ſerve to keep burning thoſe very fires, which are the inſtrumental means of its production from the divers minerals which contain that pure reſpirable fluid.

Among the other phenomena, that of the detonation of nitre is now very eaſily explained, whereas before it baffled the efforts of the greateſt philoſophers. — " Now," *ſays* Dr. PRIESTLEY, " the doctrine of dephlogiſticated air ſupplies the
" eaſieſt ſolution imaginable of this very difficult phenome-
" non: For it appears, that the nitrous acid cannot be heated
" to a certain degree, in contact with any earthy matter,
" without producing dephlogiſticated air; by the help of
" which, all combuſtible ſubſtances burn with the greateſt

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* Exper. and Obſer. vol. iv. p. 327.

" violence, much more than they can be made to burn with " in common air. Here then I ſuppoſe, that the moment the " acid of nitre, contained in the nitre, and the earth of the " coal, for example, thrown into it, become red-hot, in contact with each other, dephlogiſticated air is produced; and " in this air the remainder of the charcoal, being likewiſe red-hot, burns with the violence that is obſervable in the experiment; while, at the ſame time, other portions of the nitrous acid are forming, with other parts of the ſame decompoſed charcoal, the union that conſtitutes more dephlogiſticated air; and thus the detonation continues, till " all the charcoal, or all the nitre, is conſumed, the acid not " being *loſt*, as ſome chymiſts expreſs it; but entering into " the compoſition either of the dephlogiſticated air, or of " ſome other kind of air, that may be generated in the proceſs. Let any perſon but attend to the phenomena of the " detonation of charcoal in nitre, and that of the dipping a " piece of hot charcoal into a jar of dephlogiſticated air, and " I think it will be impoſſible for him not to conclude that " the appearances are the very ſame, and muſt have the ſame " cauſe. There is the ſame intenſe incondeſcence, and the " ſame rapid conſumption of the charcoal, in both caſes; and " this is evidently owing to the eagerneſs, as I may ſay, with " which this ſpecies of air, the moſt free from phlogiſton itſelf, " ſeizes upon the phlogiſton of other bodies, in a ſufficient

" degree of heat. Such appearances cannot be produced in
" common air; which, being more than half ſaturated with
" phlogiſton already, can take but little more, &c [*]."

CHAP. III.

Of Fixed Air, or Calcareous Gas.

IN the two preceding chapters we treated of common and dephlogiſticated air, which are the only known elaſtic fluids capable to aſſiſt reſpiration, combuſtion, and the other phlogiſtic proceſſes. All the other permanently elaſtic fluids, of which we are now going to treat, can neither be breathed, nor can they aſſiſt combuſtion. In the inveſtigation of the properties of thoſe various elaſtic fluids, I ſhall begin with thoſe which are *naturally* found in ſome particular places, and ſhall then paſs to examine thoſe which may be called intirely *artificial.* The permanently elaſtic fluids of the former claſs are, fixed, and inflammable air: all the reſt are of the latter.

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[*] Exper. and Obſer. vol. iv. p. 256.

Fixed air is a permanently elaſtic fluid, ſpecifically heavier than common air, or than any other permanently elaſtic fluid, incapable to aſſiſt reſpiration, combuſtion, &c. and of which water can abſorb a greater portion than of any other permanently elaſtic fluid, that is at all confinable by water, or that water does not abſorb in an inſtant *. But is, like common air, tranſparent, inviſible, and poſſeſſed of the ſame mechanical properties.

Fixed air is, perhaps, the oldeſt permanently elaſtic fluid, different from common air, that has been noticed by mankind; ſince it is naturally found in many ſubterranean places; and it is impoſſible but it muſt have been long known, from its fatal effects on animals, and from its extinguiſhing flame. The miners, to whom it often occurs, have, ere long, called it the *choke damp*. The idea, however, that people in general had of this elaſtic fluid was very confuſed; the more common opinion, before the time of Mr. Boyle, was, that fixed air, or rather that its effects were owing to a vapour or ſpirit diffuſed through the air of ſome particular places; hence they called it *geiſt*, i. e. ſpirit; from whence the word *gas* has been derived.

The appellation of *fixed air*, or, as others call it, *fixable air*, has been given to this permanently elaſtic fluid, becauſe it may be incorporated or fixed in various ſubſtances, as lime, &c. and becauſe it exiſts in a concentrated or fixed ſtate in divers bodies, from which it may be obtained. But it is evident, that on this account almoſt all the other ſorts of permanently elaſtic fluids ſhould alſo be called *fixed airs*; which ſhews the impropriety of the appellation, though cuſtom has rendered it familiar and diſtinct to us. The great chymiſt, Mr. BERGMAN, with more propriety calls it the aereal acid, *acidum aereum*, ſince it has been fully demonſtrated to be an acid, though a very weak one in compariſon with the other acids.

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* Vitriolic acid air, alkaline air, and other elaſtic fluids, are inſtantly abſorbed by water; ſo that here it is meant, that water abſorbs more of fixed air, than of any of thoſe permanently elaſtic fluids of which water abſorbs a part in a conſiderable time, and by a little agitation, &c. but not in an inſtant.

The *fixed air*, or *calcareous gas*, or *aereal acid*, called alſo *mephytic acid*, and *mephytic gas*, is both the production of nature, and may be obtained by art. It is found naturally in various mines, caverns, wells, and ſome other places that are not ventilated, and where it may have been formed by natural fermentation or combuſtion, as in the vicinity of vulcanos, of putrid ſubſtances, &c. And it is found in various mineral waters, out of which it is continually eſcaping; ſo that at the ſpring of ſeveral mineral waters there is generally a body of fixed air of a conſiderable depth. —It has often happened, that people, who for the ſake of the heat went to ſleep near brick-kilns, have been found dead; no doubt, owing to the fixed air, and other noxious elaſtic fluid, which is abundantly produced from the ſubſtance of the bricks in the act of baking. The *Grotto del Cane*, near Naples, has been famous for many ages, on account of the ſtratum of fixed air which exiſts at the bottom of it, and which is evidently emitted through the fiſſures of the earth. In this ſmall grotto many experiments have been, and are continually made, to ſatisfy the curioſity of travellers and philoſophers. Almoſt all the hiſtorians, and the philoſophical writers, who mention the city of Naples and its environs, take notice of this grotto. Animals of different ſpecies, and even men, have been killed, or for a time deprived of their ſenſes, by being confined cloſe to the pavement of this grotto; and lights are commonly extinguiſhed in it. JOANNIS CARAMUELIS, in his *Matheſis novo*, printed in the year 1670, vol. I. relates ſome experiments made by himſelf and others upon the noxious elaſtic fluid of the *Grotto del Cane*, which are very remarkable, conſidering the time in which they were made. He mentions, as we have already obſerved in the preceding part of this work, that the ſmoke of a candle, extinguiſhed within a certain diſtance of the pavement of the grotto, was intirely retained within the ſtratum of the noxious fluid, which reached to about 14 inches above the ground; and that if part of the ſmoke was driven out of the mouth of the grotto, it deſcended like water falling from the edge of a tub, inſtead of aſcending as ſmoke is wont to do. Had he been acquainted with the nature of fixed air, he would have eaſily underſtood that the ſmoke was retained on account of the attraction between the fixed air and the aqueous particles; and that it deſcended when driven out of the grotto, becauſe the fixed air, being ſpecifically heavier than common air, deſcended, and carried the ſmoke along with itſelf. This ingenious perſon gives a drawing of the grotto, and of the ſmoke, &c. He alſo relates another experiment, which tends to prove nothing leſs than the acid nature of fixed air. In order to collect any vapour that might proceed from the bottom of the ſaid grotto, he and his companions placed the head of an alembic on the pavement of it; and as this inſtrument was rather colder than the air of the grotto, which is generally warm *, it collected a few drops of a watery fluid, which, to the taſte of his companions, ſeemed to be acidulous, though he could not perceive it himſelf; but he adds, that his taſte is naturally not very exquiſite.

In the preſent ſtate of knowledge, this experiment is eaſily explained; for it is plain, that the head of the alembic, being colder than the air of the grotto, attracted the watery particles from it, which imbibing the fixed air, became acidulous. In ſeveral places the fixed air exiſts only for a time, and then ceaſes; in others is continually produced.

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* The ground about this grotto ſhews manifeſt ſigns of ſubterranean fire or fermentation, as it abounds with hot ſprings, ſulphur, emanations of ſmoke, &c. Pretty near it is the famous *Solfatara.*

But in general, in thoſe places wherein it is naturally found, is always mixed with much common air; hence ſometimes it extinguiſhes flame, though it is not fatal to animals that breathe it; and often ſome other elaſtic fluids are mixed with it, as inflammable and phlogiſticated air.

The artificial methods of obtaining fixed air are principally three, viz. by fermentation, by heat, and by acids.

Vegetable or animal ſubſtances, when they are fermenting, yield a quantity of fixed air, which is generally greater from vegetable than from animal bodies; and even by the ſame kind of ſubſtances, a various quantity of fixed air is produced at various times; probably, when the fermentation is made in a longer time, then a greater quantity of fixed air is produced, and contrarywiſe. In breweries, upon the ſurface of the fermenting malt, there is always a ſtratum of fixed air, which reaches as high as the edge of the vats; and ſometimes, when thoſe veſſels are very deep, and the ſurface of the fermenting liquor in them is much below their edges, the ſtratum of fixed air may be of ſome feet in depth *.

The ſame phenomenon is obſervable in the fermentation of wines in general; and it is owing to the production and elaſticity of fixed air, that when fermenting liquors are put into cloſe veſſels, thoſe veſſels are often broke with great vio-

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* Le Duc de Chaulnes has found it even 4 feet deep. See his Memoire et Experiences ſur l'Air fixe de la Biere, p. 2.

lence. In ſhort, whenever ſubſtances undergo the vinous fermentation, a quantity of fixed air is produced. Dr. Hales obtained from 42 cubic inches of beer, 639 cubic inches of fixed air, in 13 days.—From a quantity of ſugar undergoing the vinous fermentation, Mr. Cavendish obtained a conſiderable quantity of fixed air; ſo that out of 100 parts of the dry ſugar, 57 parts ſeemed to have been converted into fixed air.

Fermented liquors, notwithſtanding that a vaſt quantity of fixed air eſcaped from them during their fermentation, do ſtill contain a conſiderable quantity of fixed air, except when they are become quite vapid, or, as it is called, flat; ſo that their agreeable taſte is in great meaſure owing to the preſence of fixed air in them; from whence it follows, as is confirmed by experiments, that when wines, beer, &c. have loſt their fixed air, and are become flat, by being kept in an open veſſel, and in a warm place, or otherwiſe; their briſk and agreeable taſte may be reſtored by impregnating them again with fixed air.

Dr. Priestley, in order to obſerve the proportion of fixed air contained in different ſorts of wine, made uſe of a glaſs phial, with a ground ſtopple and tube, capable of containing $1\frac{1}{2}$ of an ounce meaſure. This he filled with each ſpecies of wine, and then plunged it into a veſſel of water, which was ſet over the fire to boil, receiving the fixed air, after the uſual manner, into a receiver filled with and inverted in quickſilver.—The reſult of his experiments is as follows *:

The quantity of permanently elaſtic fluid, which on examination was found to be pure fixed air, contained in

Madeira, was	$\frac{1}{100}$	of an ounce meaſure.
Port of 6 years old	$\frac{1}{48}$	
Hock of 5 years	$\frac{1}{24}$	
Barrelled claret	$\frac{1}{12}$	
Tokay of 16 years	$\frac{1}{20}$	
Champaigne of 2 years	2	
Bottled cyder of 12 years	$3\frac{1}{4}$	

Liquors undergoing the *acetous* fermentation, yield a conſiderable quantity of elaſtic fluid; but I do not know that the nature of it has been hitherto properly examined. From a few experiments it ſeems, that the elaſtic fluid produced in that ſtate is moſtly, though not intirely, fixed air.

During the putrefactive fermentation, ſome fixed air is produced, though not much; but then it is generally mixed with other permanently elaſtic fluids, viz. inflammable and phlogiſticated air, together with a putrid offenſive effluvium, which in great meaſure ſeems to be intimately combined with the fixed air. "It ſeems," *ſays* Dr. PRIESTLEY, "to depend, "in ſome meaſure, upon the time, and other circumſtances,

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* Exper. and Oſerv. vol. ii. p. 227.

" in the diſſolution of animal or vegetable ſubſtances, whe-
" ther they yield the proper putrid effluvium, or fixed or in-
" flammable air *."

The elaſtic fluid produced by putrefying vegetables, when kept in a moderate degree of heat, is almoſt all fixed air; whereas animal ſubſtances, in the ſame circumſtances, yield ſeveral times more inflammable than fixed air. Vegetable ſubſtances yield almoſt all the permanently elaſtic fluid in a ſhort time, generally in a few days; but animal bodies continue to produce elaſtic fluid for many weeks.

If the elaſtic fluid, produced by the putrefaction of animal ſubſtances, be cauſed to be abſorbed by water, and afterwards that water be boiled, the fixed air, which is then obtained from it, is free from the putrid effluvium.

It may be laſtly obſerved, with reſpect to the production of permanently elaſtic fluids from putrefying animal ſubſtances, that the nature of it, as well as the quantity, is different, according to the different ſubſtances employed; thus the muſcular part of an animal body will yield leſs elaſtic fluid, and leſs mixed with any putrid or offenſive effluvium, than a whole animal, or than the liver, &c. The proportion of inflammable, and of fixed air, is alſo various, according to the various parts.

It is almoſt uſeleſs to deſcribe any proceſſes by which

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[*] Exper. and Obſer. vol. i. p. 81.

fixed air may be obtained from fermenting ſubſtances; ſince every common method of making wine, beer, &c. will anſwer very well; but, for the ſake of thoſe who require a particular preſcription for every thing, I ſhall add the following proceſs, which gives a great quantity of very pure fixed air*:—Mix together equal parts of brown ſugar and good yeſt of beer, to which add about twice the bulk of water. This mixture being put into a phial, to which a bent tube with a cork may be adapted, and being expoſed to a degree of heat not exceeding the 80th or 90th degree of Farenheit's thermometer, will yield a good deal of fixed air.

Fermentation is one of the means by which fixed air is produced; but, as few bodies are capable of fermenting, it follows that this method is not ſo general as either of the other two, viz. by heat or by acids; which, indeed, force the fixed air out of a prodigious number of bodies, and in general not only in greater quantity, but alſo in a much ſhorter time, than fermentation.

In every combuſtion, excepting that of ſulphur or of metals, a quantity of fixed air is generated; which may be obſerved by fixing a lighted candle in a baſin of lime-water, and inverting a large glaſs receiver over it; for a precipitation of the lime will follow. If, inſtead of a candle, the experiment be tried with burning pieces of wood, of paper, and, in ſhort, of any combuſtible ſubſtance, except ſulphur and metals, the lime will always be precipitated, which is one of the diſtinguiſhing characteriſtics of fixed air. In the chapter on common air, we took notice of the diminution ſuffered by common air, when combuſtible bodies are burned in a given quantity of it; from whence the reader may in ſome meaſure eſtimate the quantity of fixed air generated, though this cannot be done with exactneſs.—In dephlogiſticated air the precipitation is much more conſiderable.

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* This method, and fermentation in general, may be uſed for ſome particular experiments, in which the proper produce of fermentation may be required to be examined; otherwiſe fixed air is more eaſily and more plentifully obtained by other means, to be deſcribed in the ſequel.

Dr. PRIESTLEY having heated, by means of a lens, charcoal ſtanding in a receiver full of ſome permanently elaſtic fluid that was incapable to aſſiſt combuſtion, as nitrous air, &c. and which receiver ſtood inverted in lime-water, found that no precipitation of the lime enſued *; which ſhews that fixed air cannot be produced from an inflammable body by heat only, without combuſtion. When electric ſparks are paſſed through a quantity of common air contained in a receiver that is inverted in lime-water, a diminution of the air takes place, and alſo a precipitation of the lime; which ſhows that ſome fixed air is generated. Not only the lime-water is precipitated, but even the blue juice of vegetables may be changed into red, by taking electric

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* Exper. and Obſer. vol. i. p. 136.

ſparks in a quantity of common air. Dr. PRIESTLEY having cemented a wire into one end of a glaſs tube, the diameter of which was about one tenth of an inch, and having fixed a braſs ball to that extremity of the wire which was out of the tube, filled the lower part of it with the juice of turnſole or archil, ſo that a quantity of common air was contained in the tube between the extremity of the wire and the ſurface of the liquor. Then taking electric ſparks between the ſaid wire and liquor for about one minute, the upper part of the liquor began to look red, and in about two minutes it was manifeſtly ſo. The air, at the ſame time, was diminiſhed in proportion as the liquor became red; but when the diminution arrived to be one fifth of the quantity of the air contained, then a longer electrization produced no ſenſible effect. "To determine," *ſays the Doctor*, "whether the "cauſe of the change of colour was in the *air* or in the "*electric matter*, I expanded the air which had been di-"miniſhed in the tube by means of an air-pump, till it ex-"pelled all the liquor, and admitted freſh blue liquor in "its place; but after that, electricity produced no ſenſible "effect, either on the air or on the liquor; ſo that it was "evident that the electric matter had decompoſed the air, "and had made it depoſit ſomething that was of an acid "nature *."

The calcination of metals, as we have already obſerved,

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[*] Exper. and Obſerv. vol. i. p. 184.

phlogiſticates, and conſequently diminiſhes, common air, but does not produce any fixed air, ſince the lime-water, over which the calcination is made, does not become turbid; and when metallic calxes are expoſed to a ſufficient ſtrong heat, they in general yield ſome fixed air: ſo that it ſeems that the fixed air which is formed in the act of the calcination of metals is abſorbed by the calx. Some fixed air may be obtained from red-lead, by no greater degree of heat than that of the flame of a candle applied to the phial that contains it.

Dr. PRIESTLEY, having examined the calx of lead in its various ſtates, found that it generally produced ſome fixed air, eſpecially white and red-lead; but we have, in the preceding chapter, obſerved that whenever dephlogiſticated air is extracted from any ſubſtance, a portion of fixed air is generally produced together with it. "I have obſerved," *ſays Dr.* PRIESTLEY, "that, in general, thoſe ſubſtances "which, without containing phlogiſton, yield fixed air with "heat, or by the addition of an acid, when mixed with "ſpirit of nitre, and treated as above, yield more or leſs of "dephlogiſticated air, but generally with a conſiderable mix- "ture of fixed air; though I profeſs not to know upon what "circumſtance it is that the proportion of theſe two kinds of "air, produced from theſe ſubſtances, depends *."

When metallic calxes are revived, by addition of charcoal, or other inflammable ſubſtance, ſome fixed air is alſo produced, which has been thought to proceed from the charcoal, and not from the metallic calx; but Dr. Priestley obſerves, that fixed air is extracted from ſeveral metallic ſubſtances by means of heat only, without any addition of charcoal; from whence it ſeems to follow, that the fixed air muſt be produced from the metallic calx; but yet the combuſtion of charcoal by itſelf generates fixed air; ſo that in the reduction of metallic calxes the production of fixed air muſt be attributed to both, viz. to the calx and to the charcoal, or other ſubſtance uſed.

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* Exper. and Obſer. vol. ii. p. 65.

The reader, even from that which has been already ſaid concerning metallic calxes, muſt have comprehended that the phenomena attending it are very difficultly explained; and he may be aſſured, that, notwithſtanding the vaſt number of experiments which have been hitherto made concerning it, the ſubject is ſtill imperfectly underſtood. That the inveſtigation of thoſe intereſting phenomena, relative to the calcination of metals, may be farther proſecuted, and in order to put the ſubject in the moſt advantageous proſpect for the comprehenſion of my reader, I ſhall here mention the principal facts hitherto obſerved, and ſhall point out the various weighty objections offered againſt the deductions which have been drawn from them.

Mr. Lavoisier, member of the French Academy of Sciences, who has given much attention to this ſubject, has performed a great number of experiments concerning it, which were conducted in an elegant manner, and which he has related with ſingular order and elegance in his Eſſays Phyſical and Chemical. Having diſſolved mercury in nitrous acid, and alſo iron in nitrous acid, and having precipitated the metal in either ſolution by means of chalk and by lime, he found that when chalk was uſed a greater quantity of precipitate was obtained than when lime was employed.

Now as chalk contains much more fixed air than lime, and as the precipitate is afterwards found to contain fixed air, it ſeems that the precipitation of the ſolution is owing to the abſorption of the fixed air that is ſeparated from the chalk or lime, and that more precipitate is formed when chalk is uſed than when lime, becauſe the former yields more fixed air than the latter. Mr. Lavoisier, having collected the elaſtic fluid which was generated in the reduction of minium *, and having compared it with that diſcharged from chalk, &c. found that they agreed in all their properties; which proves that they are of the ſame nature, viz. they are what we underſtand by *fixed air*, at leaſt we find no difference between them. They both precipitated the lime in lime-water, they both extinguiſhed flame, were fatal to animals, were abſorbed by water, &c. After that the greateſt part of thoſe elaſtic fluids was abſorbed by water, a ſmall portion remained, which is immiſcible with water, and is much reſembling the atmoſpheric air. This reſiduum, Mr. Lavoisier obſerves, is more conſiderable in the fixed air produced in metallic reductions, than in that detached from chalk. This judicious philoſopher, having mixed together *mercurius precipitatus per ſe* and charcoal, expoſed the mixture, in a glaſs retort, to a proper degree of heat, and collected the produced elaſtic fluid, which he found to have the properties of fixed air; but obſerving that, by reducing the precipitate *per ſe* by itſelf, without charcoal, the elaſtic fluid that is thereby produced, is ſo far from being fixed air that is it a much purer reſpirable fluid than common air, "It ſeems," *ſays he*, "to be "proved from hence, that the principle which combines "with metals during their calcination, and which occaſions "the augmentation in their weight, is nothing but an ex-"ceedingly pure portion of the air which ſurrounds us, "which we reſpire, and which paſſes, in this proceſs, from a "ſtate of expanſibility to that of ſolidity: if then it be ob-"tained in the ſtate of fixed air in all the metallic reductions "when charcoal is employed, it is to the charcoal that this "effect ſhould be attributed; and it is very probable that all "the metallic calxes would yield only common air, if we "could reduce them all without addition, in the ſame "manner as the *mercurius precipitatus per ſe.*"

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* From 144 grains of red-lead mixed with 12 grains of charcoal, previouſly well burned in a cloſe veſſel, he obtained 14 cubic inches of fixed air.

The deflagration of nitre with any inflammable ſubſtance ſhews phenomena analogous to thoſe of the precipitate *per ſe*, viz. it produces fixed air; whereas nitre, expoſed to a ſtrong degree of heat by itſelf, yields dephlogiſticated air.

To Mr. Lavoisier's obſervation a great objection is oppoſed by Dr. Priestley, who having expoſed metallic calxes to the focus of a glaſs lens, without any addition of charcoal or other inflammable body, obtained ſome fixed air from them. But it may be obſerved, that moſt metallic calxes contain ſome quantity of phlogiſton, to which the formation of fixed air may be attributed. Indeed, conſidering that fixed air is generated in every combuſtion, and that in the reduction of metallic calxes the charcoal, or other inflammable matter uſed, if proportionate to the quantity of calx, is intirely burned, it ſeems very natural to attribute the production of fixed air to the combination of the phlogiſton of the inflammable ſubſtance with the dephlogiſticated air of the metallic calx; from whence it ſeems to follow, that fixed air is a compound of pure reſpirable air and phlogiſton: but we ſhall examine this matter in the ſequel.

The principal facts that ſeem upon the whole to be aſcertained, relating to the phenomena of metallic calcination, and reduction of metallic calxes, are, I. That metals are only calcinable when expoſed to reſpirable air and heated, or when they are diſſolved in acids. II. That the calcination is performed much quicker when the air is purer and the metal expoſes a greater ſurface to it. III. That the metal acquires an additional weight by calcination, ſo that the calx weighs more than the metal employed; and that the calx loſes part of its weight when reduced, ſo that the metal weighs leſs than the calx employed. IV. That in the act of calcination a quantity of air is abſorbed, and the reſt of the air (when the experiment is performed in confined air) is phlogiſticated, but no fixed air is found in it. V. That in the reduction of metallic calxes, if they are capable of being revivified without addition, dephlogiſticated air is moſtly produced; otherwiſe fixed air is yielded. VI. and laſtly, That metallic calxes, when expoſed by themſelves to a ſufficient degree of heat, yield, in general, dephlogiſticated air, but moſtly mixed with a ſmall portion of fixed air.

The calcareous earths, which, when acted on by acids, yield a vaſt quantity of fixed air, produce a very ſmall quantity of it when expoſed to a ſtrong heat by themſelves, in a proper veſſel, even when expoſed to the focus of a lens *. Dr. Priestley, in his experiments relating to the production of dephlogiſticated air from various ſubſtances, when moiſtened with nitrous acid, and afterwards expoſed to a ſufficient degree of heat, generally found that ſome fixed air was produced together with the dephlogiſticated air; but often obtained fixed air only, without any dephlogiſticated air being mixed with it, or fixed and nitrous air together. From half an ounce of *ruſt of iron*, moiſtened with ſpirit of nitre, and dried, he obtained about a quart of elaſtic fluid, about one third of which was fixed, and the reſt nitrous air. From aſhes of pit-coal, treated in the ſame manner, he obtained nearly the like reſult †. But in thoſe experiments, the Dr.

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* Exper. and Obſer. vol. ii. p. 120.

† Ibid. vol. ii. ſect. iv.

moſtly uſed a gun-barrel, into which he introduced the ſubſtances to be tried; ſo that it is very probable, as he juſtly obſerves, that the iron might have contributed to the formation of the fixed air. In fact, when he tried ſubſtances of the ſame ſort, firſt in a gun-barrel, and then in glaſs veſſels, he obtained much more fixed air in the former than in the latter caſe. One of thoſe experiments he made with tobacco-pipe-clay, which, after being moiſtened with ſpirit of nitre, was, when dry, expoſed to the fire in a gun-barrel, and yielded ſome elaſtic fluid, which appeared to be wholly fixed air; but repeating the experiment in a glaſs-phial with a ground ſtopple, and taking the produced elaſtic fluid at eight different times, found that on the beginning ſome fixed air was produced, but afterwards the produce was dephlogiſticated air *. He made a ſimilar experiment with *flints carefully calcined in cloſe veſſels*, and obtained a ſimilar reſult *.

From an ounce of *common ſalt*, expoſed to as great degree of heat as could be given it in a glaſs retort, Dr. PRIESTLEY obtained about two ounce meaſures of elaſtic fluid, the firſt part of which was fixed air, and the laſt phlogiſticated air. From ſolutions of iron in ſpirit of ſalt, of quick-lime in ſpirit of ſalt, and from moſt metallic and other ſalts, the Dr. has alſo obtained ſome fixed air, viz. from green, blue, and white vitriol, from calcined alum, from vitriolated tartar, from borax, and from ſugar ‡.

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* Exper. and Obſer. vol. ii. ſect. 4.

‡ Ibid. vol. ii. ſect. 6. and vol. iv. ſect. 24.

Moſt minerals contain fixed air, which may be extracted to a certain degree by means of heat. Mr. KRENGER, diſtilling a *greeniſh fuſible ſpar*, which was luminous in the dark, obtained from it ſome permanently elaſtic fluid, which, like fixed air, cryſtallized a ſolution of fixed alkali. Mr. FONTANA, in his analyſis of the *malachite*, finds that that mineral contains a vaſt quantity of fixed air, as pure as that which is extracted from chalk by means of vitriolic acid. One ounce of malachite is capable of yielding about 170 cubic inches of fixed air, when expoſed to a pretty ſtrong fire by itſelf, in a glaſs matraſs †.

From almoſt every metallic ore and earthy mineral ſome fixed air may be obtained, as well as from chalk, lime-ſtone, marble, marine ſhells, fixed and volatile alkali, and from magneſia alba, by means of a violent fire, or of acids.

Mr. ELLER, from two drams of *crabs eyes*, mixed with one ounce of vinegar, obtained 12 cubic inches of fixed air; but from an equal quantity of the ſame ſubſtance, with one ounce of ſpirit of ſalt, obtained 75 cubic inches of fixed air. From two drams of *red coral*, with one ounce of ſpirit of ſalt, he obtained 52 cubic inches of fixed air.

And from one ounce of *ſalt of tartar*, mixed with half an ounce of ſpirit of nitre, he obtained 48 cubic inches of fixed air.

Dr. BLACK, of Edinburgh, obſerves, that magneſia contains half its weight of fixed air. And Mr. WILLIAM BEWLY, having expoſed magneſia in an oblong glaſs-phial to a ſand-heat, found, that although the portion of it, which had been made red-hot, did not originally weigh above one dram and a half, as he afterwards calculated, the fixed air produced was above 30 ounce meaſures.

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† Journal de Phyſique, 1778.

Mr. CAVENDISH ſays, that marble contains $\frac{407}{1000}$ parts of its weight of fixed air * ; that *cryſtals of ſalt of tartar* yield $\frac{428\frac{1}{4}}{1000}$ of their weight of fixed air ; and that *volatile ſalt ammoniac* yields about $\frac{528}{1000}$ of its weight of fixed air.

Mr. BERGMAN ſays, that dry ſalt of tartar ſeldom contains above $\frac{23}{100}$ of fixed air, $\frac{5}{100}$ of water, $\frac{2}{100}$ of ſiliceous earth, and $\frac{70}{100}$ of pure alkali †.

Mr. JACQUIN, in his *Examen doctrinæ Mayerianæ*, aſſerts, that *lime-ſtone*, or *cremor calcis*, contains $\frac{13}{32}$ parts of its weight of fixed air.

The ingenious author of a treatiſe on *gaſes*, ſays to have obtained 16 ounce meaſures of fixed air from the deflagration of one pennyweight of nitre, and an equal quantity of powdered charcoal, well mixed with two ounces of clean ſand, to prevent the too haſty deflagration, when expoſed to heat in a retort.

In Mr. BOYLE's, Dr. BOERHAAVE's, and Dr. HALES's works, and in other books, the quantities of elaſtic fluid generated in various proceſſes, and by divers ſubſtances, are mentioned with diſtinction; but as thoſe writers were not acquainted with the characteriſtic properties of fixed air, we don't know whether the elaſtic fluid mentioned by them was pure fixed air or not.

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* Phil. Tranſ. for the year 1776.

† Bergman de acido aere, ſect. 7.

In his fourth vol. of Experiments and Obſervations, ſect. xxxvi. Dr. PRIESTLEY mentions to have obtained from one ounce of cream of tartar, in a glaſs veſſel and a ſand-heat, 170 ounce meaſures of elaſtic fluid, the firſt portions of which were almoſt pure fixed air. The reſiduum, however, was inflammable, and burned with a blue flame.

At laſt only about two thirds of the elaſtic fluid was fixed, and the reſt inflammable air.—This ſubſtance, by calcination in a red-heat, loſt about half its weight, after which it ſtill retained a great deal of fixed air, which was yielded when ſpirit of ſalt was poured upon it.

Dr. PRIESTLEY found, that when nitrous acid is mixed with nitrous or vitriolic ether, or any eſſential oil, and alſo when mixed with tallow or bees-wax, it produces ſome fixed air, ſometimes mixed with a little nitrous air. "Spirit of nitre," *ſays he*, "heated with *olive oil*, yields the ſame kind of air "with that which is produced from eſſential oils, &c. but "the proceſs is exceedingly troubleſome, owing to the te-"nacity of the oil."

From either *gum-arabic*, *gum-copal*, or *amber*, mixed with ſpirit of nitre, the Doctor obtained ſome fixed air mixed with nitrous air [*].

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[*] The nitrous air thus obtained was often as good as that extracted from metals; and the reſult of the proceſs ſeemed not to depend upon the ſtrength of the ſpirit of nitre employed.

From a quantity of *fluor* and ſtrong nitrous acid he alſo obtained one ſixth of fixed and the reſt nitrous air[*].

In general, he obſerves, "that if the ſubſtance with which "the ſpirit of nitre is heated, whether it be fluid or ſolid, "contain much phlogiſton, the air produced from it will be "nitrous air, or poſſeſs the property of diminiſhing common "air to a conſiderable degree; and in almoſt all caſes, with "a mixture of fixed air[†]."

From animal ſubſtances, treated as the above-mentioned ſubſtances, viz. mixed with ſpirit of nitre, and ſometimes heated a little, in order to facilitate the production of elaſtic fluid, Dr. PRIESTLEY obtained, in general, fixed air; but whereas the fixed air produced by a ſimilar proceſs with vegetable ſubſtances is moſtly mixed with nitrous air, this is mixed with an elaſtic fluid, which is ſeldom nitrous in a very ſlight degree, but is often phlogiſticated air, viz. in ſuch a ſtate as extinguiſhes a candle, does not diminiſh common air, nor is itſelf diminiſhed by nitrous air. Towards the end of the proceſs, the Doctor remarks, "that when, by means of "a ſtrong heat, the produce of air is very rapid, and the air "full of clouds, it is, like air produced from vegetable ſub-"ſtances in the ſame circumſtances, ſlightly inflammable, "burning with a lambent, greeniſh, or blueiſh flame[‡]."

The calcareous ſubſtances, in general, produce abundance of fixed air, when acted on by any acid, only the ſtrongeſt acids will expel from them more fixed air than the weakeſt; and it happens to be peculiarly advantageous for thoſe who want to produce a great quantity of fixed air, that the vitriolic acid is both the cheapeſt and ſtrongeſt acid, and, upon the whole, the fitteſt for this purpoſe. The phenomena attending the production of fixed air from calcareous ſubſtances, &c. are themſelves very remarkable, and furniſh the ſubject of much ſpeculation in philoſophy.—The principal facts are the following:—I. When calcareous earths, alkalies, and magneſia, in their uſual ſtate, are mixed with acids, they cauſe an effervеſcence, and conſequently the production of a permanently elaſtic fluid, namely, fixed air. II. Theſe ſubſtances retain the fixed air very obſtinately; ſo that a ſtrong fire is neceſſary to expel it from magneſia, and the ſtrongeſt is not ſufficient to expel it entirely from fixed alkalies, and eſpecially from calcareous earths *. When theſe ſubſtances are treated with acids, they yield the fixed air, becauſe they have a ſtronger attraction to thoſe acids than to the fixed air. III. The calcareous earths which are inſoluble in water, when deprived of the fixed air become ſoluble in it. Thus lime-ſtone is not ſoluble in water, but lime (viz. lime-ſtone deprived of its fixed air) is ſoluble in water. And if thoſe ſubſtances deprived of their

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[*] Exper. and Obſer. vol. iii. p. 288.

[†] Ibid. vol. ii. ſect. 7.

[‡] Ibid. vol. ii. ſect. 8.

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* Chalk, lime-ſtone, &c. after being kept in a very ſtrong fire for many hours, if they are put into acids, yield a conſiderable quantity of fixed air; which ſhews that the pureſt quick-lime contains ſome fixed air.

fixed air, are put in a ſituation proper to recover their loſt fixed air, they loſe the property of being ſoluble in water. Thus, when lime-water is expoſed to fixed air, the lime abſorbs the fixed air, and, loſing at the ſame time its property of being ſoluble in water, is precipitated from it in the ſtate it was before calcination *, viz. of a calcareous earth inſoluble in water, and capable of effervescing with acids †. IV. Alkalies, both fixed and volatile, when deprived of their fixed air, become more cauſtic, and more powerful ſolvents, incapable of cryſtallization, and of effervescing with acids. But if to thoſe alkalies, and alſo earths rendered more cauſtic, their fixed air be reſtored, they acquire at once all the properties they had before they were deprived of the fixed air, viz. they become more mild, effervesce with acids, recover their weight, &c.

Thoſe properties of calcareous earths and alkalies were aſcertained by the learned Dr. BLACK, who performed a variety of deciſive and well-contrived experiments, upon which he

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* Lime may be precipitated from water by ſome other ſubſtance, as ſpirit of wine, beſides fixed air. But, as Dr. BLACK juſtly obſerves, in that caſe the precipitated lime is ſtill lime ſoluble in pure water, and not calcareous earth; for it does not effervesce in acids. Here the precipitation is occaſioned, not by the ſpirit of wine combining with the lime, but by its combining with the water.

† When lime-water is left expoſed to the open air for a conſiderable time, the lime is alſo precipitated from it in the form of calcareous earth, called *cremor calcis*; ſo that it muſt have acquired the fixed air from the atmoſphere.—The induration of the mortar uſed in buildings, muſt be alſo attributed to the ſame cauſe.

formed a juſt theory, viz that the cauſticity, ſharpneſs, ſolubility, &c. of thoſe ſubſtances, was owing to the fixed air being expelled from them; and that when they were combined with a proper quantity of fixed air, they were mild, &c *.

The Dr. gives the epithet of *mild* to thoſe ſubſtances when they are combined with air, and of *cauſtic* when deprived of it, as *cauſtic calcareous earth*, *cauſtic fixed alkali*, &c.

Among the other experiments, Dr. Black connected two phials by means of a bent tube; in one of which he put ſome cauſtic ſpirit of ſalt ammoniac, and in the other ſome mild alkali, or mild calcareous earth; then pouring through

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" * Theſe conſiderations led me to conclude, that the relations between fixed " air and alkaline ſubſtances was ſomewhat ſimilar to the relation between " theſe and acids; that, as the calcareous earths and alkalies attract acids ſtrong" ly, and can be ſaturated with them; and, when we mix an acid with an alkali, " or with an abſorbent earth, that the air is then ſet at liberty, and breaks out " with violence; becauſe the alkaline body attracts it more weakly than it does " the acid, and becauſe the acid and air cannot both be joined to the ſame " body at the ſame time.

" I alſo imagined, that, when the calcareous earths are expoſed to the action " of a violent fire, and are thereby converted into quick-lime, they ſuffer no " other change in their compoſition, than the loſs of a ſmall quantity of water, " and of their fixed air. The remarkable acrimony which we perceive in them " after this proceſs, was not ſuppoſed to proceed from any additional matter " received in the fire, but ſeemed to be an eſſential property of the pure earth, " depending on an attraction for thoſe ſeveral ſubſtances which it then became " capable of corroding or diſſolving, which attraction had been inſenſible as " long as the air adhered to the earth, but diſcovered itſelf upon the ſepara" tion." Dr. Black's Exper. on Magneſia Alba, Quick-lime, &c.

a hole made in the ſide of the latter phial, ſome acid upon the mild alkali, ſo as to produce ſome fixed air, which, paſſing through the tube into the other phial, combined with the ſpirit of ſal ammoniac, and rendered it mild.

Dr. BLACK even determines the degrees of affinity between fixed air and the above-mentioned ſubſtances, viz. that fixed air has an attraction, firſt to calcareous earth, next to fixed alkali, then to magneſia, and laſtly to volatile alkali; ſo that mild volatile alkali may be deprived of its fixed air, or may be rendered cauſtic, by applying to it magneſia previouſly deprived of its fixed air, or cauſtic fixed alkali, or quick-lime *.

Dr. BLACK ſeems to have been the firſt who remarked, that when metals are precipitated from acids in which they are diſſolved, by the addition of a mild alkali, or calcareous earth, the fixed air is ſeparated from the alkali or earth, and is combined with the metallic precipitate. He alſo attributes

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* Notwithſtanding the conviction with which this theory ſeems to be attended, " it has yet met with much oppoſition from ſome German and French " chymiſts, who adopt the theory of Mr. MAYER, concerning the principle " which he called *acidum pingue*. On the other ſide, Dr. BLACK's doctrine " has been ably ſupported and confirmed by Mr. JACQUIN, in a treatiſe called " *Examen Chemicum Doctrinæ Mayerianæ de Acido pingui et Blackianæ de aere* " *fixo*. And this treatiſe has been attacked by Mr. CRANTZ, in his *Rectificatio* " *Examinis Chemici Doctrinæ Mayerianæ*, &c."

Mr. LAVOISIER, after all, undertakes a ſeries of accurate experiments in order to clear up this diſpute, which, as appears from his Eſſays Phyſical and Chymical, confirms the truth of Dr. BLACK's experiments and theory, without leaving any apparent doubt concerning it.

the fulminating property of *fulminating gold* to the fixed air, which adheres to the gold precipitated by mild alkalies.

Some time ago, when the ſubject of elaſtic fluids was juſt beginning to be elucidated by Dr. PRIESTLEY, it was ſuppoſed by ſome perſons, that the acidulous taſte given to water impregnated with fixed air, was owing, in great meaſure, if not wholly, to ſome vitriolic acid, which did either proceed from the calcareous ſubſtances employed, or from the vitriolic acid itſelf, in caſe this was uſed for the production of fixed air from the calcareous ſubſtances, in the manner commonly practiſed. At the ſame time ſeveral perſons doubted, whether the water impregnated with fixed air contained any acid at all, ſince it had not the property of reddening the ſyrup of violets, which is one of the great characteriſtics of acids. At preſent (it being well known, that whatever acid be employed for the production of fixed air; that when no acid at all is uſed; and, in ſhort, that in whatſoever manner the fixed air is produced, it does always poſſeſs the ſame properties, and gives the very ſame taſte to the water impregnated with it) one can hardly ſuſpect that its acidity is owing to the vitriolic acid[*]; but, from the accurate experiments and obſervations made by various philoſophical perſons, eſpecially by the ingenious Mr. W. BEWLY, and by the great chymiſt Mr. BERGMAN, it appears, that fixed air is an acid *ſui generis*, which poſſeſſes the characteriſtic properties of acids in general, and has ſome other peculiar properties, by which it differs from other acids.—Mr. HEY, obſerving that water impregnated to ſaturation with fixed air, does not redden the ſyrup of violets, and that it neither efferveſces nor ſhews any clouds when mixed with fixed or volatile alkali (which effects are ſenſibly produced by water mixed with oil of vitriol, even in the proportion of one drop of acid to a pint of water) ſeems to prove, that there is no vitriolic acid in water impregnated with fixed air *. Upon this Mr. BEWLY juſtly obſerves, that fixed air is ſo rare an acid, and is ſo greatly diluted in water, when this is even ſaturated with it, "that," ſays he, "many of the blue juices reſiſt its "action upon them; while others, more ſenſible teſts of "acidity (ſuch as infuſions of *litmus*, *cyanus*, or *cornflower*, "and a few others) readily announce its acid quality.—As "to its not producing an efferveſcence with alkalies, it will "appear from the following experiments, that ſuch efferveſcence is, from the very nature of the thing, impoſſible in "the preſent caſe, in which the very contrary of an efferveſcence muſt take place. In all other caſes, when an acid "is added to a mild alkali, the *mephitic acid*, as being the "leaſt powerful of all the acids, is *expelled*, in its ſtate of "*vapour*, or in elaſtic bubbles, which conſtitute the appear-

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[*] It has been pretended, that fixed air had different properties, according to its different origin; but this is not true, and probably the miſtake may have been occaſioned from the ignorance of diſtinguiſhing other elaſtic fluids that are produced with it.

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* Appendix to PRIESTLEY's Exper. and Obſer. vol. i. N° 1.

" ance called an effervefcence; whereas, when the mephitic " acid itſelf is added to an alkali, it is *condenſed*, and ſilently " abſorbed in it †."

Mr. Bewly found, that paper tinged blue, eſpecially with the ſcrapings of radiſhes, being applied to a ſtream of fixed air, whether any acid or not had been employed in its production, the paper was preſently turned red *; that having diluted ſome liquid *hepar ſulphuris*, in which the alkali was fully ſaturated with the ſulphur, with rain-water, and having added to the ſolution ſome water impregnated with fixed air, the reſult was ſimilar to the effect produced by the addition of an acid to the ſame ſolution, (viz. the liquor became whitiſh and opaque, ſome of the ſulphur being precipitated on the alkali's combining with the fixed air); and that having diluted ſyrup of violets with water, and having alſo made different infuſions of ſome other blue vegetable flowers, he added to each of them a few drops of a ſolution of fixed alkali, ſufficient to turn them to a green colour; then, on impregnating thoſe various ſolutions with fixed air, the infuſion of litmus was turned red, and the other infuſions loſt their green colour. This ingenious philoſopher farther diſcovered, that mild fixed alkali, and alſo volatile alkali, may be neutralized by fixed air, one ounce meaſure of the latter being about ſufficient to neutralize between three and four grains of fixed alkali. This may be obſerved in the following manner:—Fill a ſmall phial with a ſtrong ſolution of mild fixed alkali, and invert it into a cup containing the ſame ſolution, or in quickſilver, then, by means of a bent tube, throw ſome fixed air into the ſaid phial, which will diſappear as ſoon as it touches the ſolution.

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† Appendix to Priestley's Exper. and Obſer. vol. ii. N° 1.

* If the infuſions of flowers, that are turned red by fixed air, be expoſed to the open air, the redneſs vaniſhes in a few hours, the fixed air eſcaping, eſpecially in a hot place.

In this manner a great quantity of fixed air will be made to diſappear, excepting the ſmall reſiduum of common or phlogiſticated air, which does always exiſt in fixed air; and the alkaline ſolution gradually loſes its diſagreeable ſharp taſte in proportion as it imbibes more and more fixed air.

Mr. BERGMAN, after having expoſed a ſolution of vegetable alkali in water to a large quantity of fixed air, did afterwards remove it into a dry place, keeping it in an open wide veſſel. Some weeks after, he found ſeveral cryſtals formed at the bottom and on the ſides of the veſſel. They were of a priſmatic form, did not deliqueſce in the open air, and in a temperate degree of heat, they were diſſolved in four parts of water. Theſe cryſtals being expoſed to a ſtrong fire, loſt $\frac{52}{100}$ of their weight, but when diſſolved ſlowly in acids they loſt $\frac{20}{100}$ of their weight; therefore it appears, that in 100 parts of thoſe cryſtals there are contained 32 parts of water, 20 of fixed air, and 48 of pure alkali. The cauſtic mineral alkali, being treated in a ſimilar manner, produced *decaedrous* or *octoedrous* cryſtals, having two oppoſite angles moſtly truncated. In 100 parts of thoſe cryſtals ſeems to be contained 16 of fixed air, 64 of water, and 20 of pure alkali.

By properly calculating the weight loſt by volatile alkali, in its being rendered cauſtic, &c. Mr. Bergman deduces that in 100 parts of concrete volatile alkali there are 12 parts of water, 45 of fixed air, and 43 of alkali *.

Upon the whole, it appears, conſidering the above-mentioned experiments, and alſo the cryſtallization of oil of tartar by fixed air, together with other obſervations, that this permanently elaſtic fluid is an acid different from the other known acids; that the acid principle is eſſential to its conſtitution, and not an acid added to a permanently elaſtic fluid; at leaſt they come and go together, ſo that when the acid is deſtroyed, the elaſtic fluid vaniſhes; and that fixed air, in whatever manner produced, does always poſſeſs the ſame, and not, as it has been pretended, various properties. It may nevertheleſs happen, that in ſome circumſtances the fixed air may appear to have ſome unuſual properties; but this may, to all probability, be owing to the accidental mixture of ſome other ſubſtance, ſince it is not improbable that fixed air, like common air, may be in ſome meaſure altered by the intervention of ſome other extraneous matter †.

Mr. Fontana's experiments and obſervations, publiſhed in *le Journal de Phyſique* for the year 1778, ſhew that almoſt all the animal and vegetable acids owe their acidity to a vaſt quantity of fixed air they contain. At leaſt thoſe experiments ſhew, that when various animal and vegetable acids are deprived of their fixed air, their acidity vaniſhes, and that when their acidity is by ſome means or other deſtroyed, fixed air eſcapes from them. Mr. FONTANA firſt examined the acid of *ants*, diſcovered by the great chymiſt Mr. MARGRAFF. He ſaturated cauſtic fixed alkali with the acid which is extracted from ants, both by diſtillation of thoſe inſects, and by expreſſion; then, having firſt evaporated and cryſtallized this ſalt, expoſed ſome of it to a ſand-heat in a glaſs veſſel, and obtained fixed air from it, with a conſiderable reſiduum of phlogiſticated and inflammable air.

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* De Acido Aereo.

† For this reaſon the nitrous and marine acids ſhould not be uſed in the production of fixed air, on account of their volatility.

"All the experiments," *ſays he*, "we have related
"on the acid obtained from ants by diſtillation, ſhew, at
"leaſt as I think, that this acid is nothing elſe but fixed air,
"like that obtained from other bodies by means of fire, of
"acids, or of fermentation. The certain fact at leaſt is, that
"all this acid is reſolvable into fixed air, and that no other
"acid is found in the alkaline ſalts we have employed."

Beſides the acid of ants, Mr. FONTANA ſays to have examined the acid that may be extracted from ſome other animal ſubſtance, as from milk, from fat, from the chyle, from butter, from ſperma-ceti, and to have found it to conſiſt alſo of fixed air. He only excepts the phoſphoric acid, which he has not yet ſucceeded to decompoſe.

As for the vegetable acids, it was Mr. BERTHOLLET who firſt advanced that their acidity was nothing more than fixed air. This opinion was founded upon the two following experiments of his, viz. He expoſed to a ſtrong fire the acid of tartar extracted by means of nitrous acid, and obtained a conſiderable quantity of fixed air, which he eſtimates to be about 700 the bulk of the acid employed. He alſo diſtilled one ounce of *terra foliata tartari*, and obtained from it fixed air mixed with a good portion of inflammable air; and ſome liquor came alſo over into the receiver. He conjectures that one ounce of *terra foliata tartari* contains 147 grains of alkali, and 429 grains of acid; which quantity of acid conſiſts of about 131 grains of fixed air, 130 grains of inflammable air, and 168 grains of oil and phlegm.—Upon thoſe two experiments Mr. Berthollet's propoſition ſeems too weakly eſtabliſhed; but Mr. Fontana's numerous and accurate experiments ſeem to have confirmed it beyond any doubt. He obtained from an ounce of cream of tartar, by means of heat only, in a glaſs veſſel, 62 grains of a very acid fluid, (which, by being neutralized by alkalies, and expoſed to proper heat, may be all converted into fixed air) 16 grains of oil, and 755 cubic inches of elaſtic fluid, conſiſting of fixed, inflammable, and very little common air *. In a ſimilar manner he converted the acid of vinegar into fixed air, viz. from one ounce of the *terra foliata tartari* he obtained

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* When the fixed air had been abſorbed by water, the reſiduum, although inflammable, was in ſome meaſure diminiſhed by nitrous air, for which reaſon Mr. Fontana ſays that ſome common air was contained in it; for pure inflammable air is not diminiſhable by nitrous air.

310 cubic inches of elaſtic fluid, conſiſting of half fixed and half inflammable air. From one ounce of extract of vinegar he obtained 479 cubic inches of elaſtic fluid; the greateſt part of which was fixed air and the reſt inflammable. One ounce of ſalt of vinegar yielded 440 cubic inches of elaſtic fluid, conſiſting of two thirds of fixed and one third of inflammable air. Other mixtures of vinegar, with divers ſubſtances, gave alſo fixed and inflammable air. An ounce of the ſalt of tamarinds, expoſed to the fire, yielded 600 cubic inches of permanently elaſtic fluid, conſiſting of three quarters fixed, and the reſt inflammable air. One ounce of concentrated juice of citron yielded 336 cubic inches of partly fixed and partly inflammable air, about 60 grains of oil, and 200 grains of an acid liquor, the acid part of which may be alſo converted into permanently elaſtic fluid, conſiſting of partly fixed and partly inflammable air.

One ounce of ſalt of verjuice, expoſed to the fire, yielded an acid liquor, ſome oil, and 322 cubic inches of elaſtic fluid, $\frac{5}{7}$ parts of which was fixed, and the reſt inflammable air.

He obtained nearly the ſame produce from all the other vegetable ſalts that he examined [*]. From an ounce of

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[*] "Il eſt à obſerver qu'on peut retirer de tous ces lecs, & de toutes les "autres ſubſtances végétales, plus au moins d'air fixe, d'air inflammable & "d'air commun, d'huile & de liqueur acide, ſuivant la manière dont elles ſont "préparées, & ſuivant le degré de feu qu'on y applique, & ſuivant pluſieurs "autres circonſtances qu'on peut varier à volonté. Mais il n'eſt pas toujours vrai que lorſqu'on a retiré tout l'air fixe des ſubſtances acides végétales, "ces memes ſubſtances perdent toute leur acidité."

Bergman's acid of ſugar, by the action of fire only, Mr. Fontana obtained 432 cubic inches of elaſtic fluid, one third of which was fixed and the reſt inflammable air, that was a little diminiſhable by nitrous air. From the acid ſalts of other ſaccharine ſubſtances he obtained nearly the ſame reſult. An acid liquor generally came over in the decompoſition of thoſe ſubſtances, the acid part of which liquor could be reſolved into fixed air without leaving back the leaſt acidity.

From all the various eſſential ſalts and dry extracts, as they are commonly prepared for medicine, like the ſalt of ſenna, ſalt of jalap, &c. Mr. Fontana obtained, by the action of fire, ſome fixed air, inflammable air, oil, and an acid liquor, as in the decompoſition of the above-mentioned ſubſtances.

Amongſt the various other objects, Mr. Fontana examined alſo, in a ſimilar manner, reſins, gums, and other ſubſtances analogous to them *. Upon the whole, he finds that their acid part conſiſts of fixed air; ſo that he thinks, that from his numerous experiments it appears, that the acid part of animal and vegetable ſubſtances, of gums and reſins, is of the

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* "J'ai ſoumis les ſubſtances gommeuſes à la meme analyſe que les ſubſtances réſineuſes; j'en ai retiré leurs acides en les diſtillant au feu, & j'ai pu "réduire tous ces acides en air fixe:

"Les huiles eſſentielles, & les huiles graſſes vegetales m'ont donné par mes "procédés un acide qui n'eſt que de l'air fixe.

"L'acide contenu dans le cire eſt auſſi de l'air fixe.

"Il paroit donc démontré, que toutes ces ſubſtances ont un acide de la meme "nature, & que cet acide eſt de l'air fixe. Et il paroït bien ſur après cela, que "les gommes & les réſines doivent leur origine au règne végétal.

the ſame nature, namely, *fixed air* concentrated or reduced into a liquid form by its union with ſome baſis.

Thoſe facts do evidently render the cauſe of the formation of fixed air in combuſtion very doubtful ; ſince one cannot with certainty ſay, whether the fixed air formed in that caſe proceeds from the atmoſphere, viz. from a combination of common air with the phlogiſton of the burned body, or is detached from the burning ſubſtance itſelf.

The experiments and obſervations hitherto mentioned ſhew, that fixed air exiſts in vaſt quantity in various bodies, which have not the leaſt appearance of acidity ; that ſome other bodies are very acid, and contain proportionably leſs fixed air ; that the fixed air in thoſe bodies cannot retain its elaſtic form ; and that thoſe bodies, when deprived of the fixed air they naturally contain, are decompoſed, ſo as to loſe ſome of the properties they had before *.

Dr.

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* Mr. Kirwan, in the 71ſt vol. of the Phil. Tranſ. gives an account of his ingenious method of finding the ſpecific gravity of fixed air in its fixed ſtate, when combined with calcareous earth ; from which it appears, that fixed air, in that ſtate, is prodigiouſly concentrated, and, were it poſſible to exiſt by itſelf in that concentrated ſtate, it would be the heavieſt body known, gold and platina excepted.

Mr. Kirwan firſt aſcertained the ſpecific gravity of a piece of white marble, then expelled the fixed air from a known weight of it finely powdered, by means of diluted vitriolic acid ; the bulk and weight of the obtained fixed air being aſcertained. Next, he calcined a known quantity of the ſame ſort of marble, by keeping it in a white heat for the ſpace of 14 hours ; after which, being weighed again, and from the weight loſt by this calcination, the weight of the fixed air, which muſt have eſcaped from it according to the above-mentioned experiment, being ſubtracted, the remainder is the weight of water contained

Dr. Priestley, conſidering the origin of fixed air, thinks, that this permanently elaſtic fluid may be a modification of

tained in the marble; from which experiments it appears, that 100 grs. of the marble contained 32,42 grs. of fixed air, 11,66 grs. of water, and 55,92 grs. of pure calcareous earth.

“ I next,” *ſays he*, “ proceeded to diſcover the ſpecific gravity of the lime. Into a braſs box, which weighed 607,65 grs. and in the bottom of which a ſmall hole was drilled, I ſtuffed as much as poſſible of the finely-powdered lime, and then ſcrewed the cover on, and weighed it both in air and in water. When immerſed in this latter, a conſiderable quantity of common air was expelled; when this ceaſed, I weighed it. The reſult of this experiment is as follows:

	Grains.
“ Weight of the box in air — — —	607,65
“ Its loſs of weight in water — — —	73,75
“ Weight of the box and lime in air — —	1043,5
“ Weight of the lime ſingly in air, — — —	435,85
“ Loſs of weight of the box and lime in water — —	256,5
“ Loſs of weight of the lime ſingly — — —	182,3

“ Hence, dividing the abſolute weight of the lime by its loſs in water, its ſpecific gravity was found to be 2,3908.

“ From theſe data I deduced the ſpecific gravity of fixed air in its fixed ſtate; for 100 grs. of marble conſiſt of 55,92 of earth, 32,42 of fixed air, and 11,66 of water. And the ſpecific gravity of the marble is 2,717. Now the ſpecific gravity of the fixed air, in its fixed ſtate, is as its abſolute weight, divided by its loſs of weight in water; and its loſs of weight in water is as the loſs of 100 grs. of marble, *minus* the loſſes of the pure calcareous earth and the water.

“ Loſs of 100 gr. of marble $=\frac{100}{2,717}=36,8$ grs.

“ Loſs of 55,92 grs. of calcareous earth $=\frac{55,92}{2,39}=23,39$ grs.

“ Loſs of 11,66 grs. of water = - - - - - $\underline{11,66}$

$35,05$

“ Then the loſs of the fixed air $36,8-35,05=1,75$; conſequently its ſpecific gravity is $\frac{32,42}{1,75}=18,52$.”

the nitrous or vitriolic acid. The finding a great proportion of fixed air in every proceſs for procuring nitrous air, except from metals; and particularly the production of fixed air from nitrous acid mixed with various ſubſtances which of themſelves give no fixed air, even when expoſed to a violent fire, ſeem to have induced him to conſider the fixed air as a modification of that acid. The fact upon which he lays the greater ſtreſs is, the production of fixed air from ſpirit of wine, when mixed with nitrous acid. He alſo obtained fixed air from vitriolic acid mixed with ſpirit of wine, or with ether; upon which, "I think," *ſays he*, "it is pretty evident, that fixed air is a *factitious ſubſtance*; and that the "vitriolic, as well as the nitrous acid, may be converted "into it *."

Conſidering the above-mentioned experiments of Mr. Fontana, which ſhew that fixed air is obtained from the decompoſition of almoſt every vegetable ſubſtance; that the action of acids is often capable to extricate permanently elaſtic fluid, of ſome ſort or other, from ſeveral bodies, in general much more eaſily than the action of fire; we may remark, that the converſion of the vitriolic or nitrous acid into fixed air, does by no means appear to be ſo evident as the formation of dephlogiſticated air out of the nitrous acid.

Let us now examine the various other properties of fixed air; viz. its ſpecific gravity, its medicinal virtue, its action upon animal and vegetable life, &c. &c.

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* Exper. and Obſer. vol. iv. ſect. 35.

Calling the ſpecific gravity of common air *unity*, the gravity of fixed air is, according to Mr. FONTANA, 1,449; according to Mr. CAVENDISH, 1,57; according to Mr. LAVOISIER, 1,233; and according to Mr. BERGMAN, 1,5 [*].—A cubic inch of fixed air was found, by Mr. FONTANA, to weigh 0,57 of a grain, the barometer being at a mean height, and the thermometer at 55°.

Fixed air has a kind of weak acid taſte or pungency; ſo that when the ſtream of it is iſſuing out of the aperture of a veſſel, in which it is contained or produced, if the mouth or noſtrils be preſented to it, they will be affected with a peculiar and rather pleaſing pungency [†].

Fixed air extinguiſhes flame, and even a red-hot piece of charcoal or wood. When a lighted wax-candle is let down into a veſſel containing fixed air, its flame is inſtantly put out; and the ſmoke, being attracted by the fixed air, diſpoſes itſelf into parallel ſtrata like clouds, and is long retained in the fixed air, which remains in the uncovered veſſel for a conſiderable time. Mr. CAVENDISH found, that even a mixture of one ninth of fixed, and the reſt common air, extinguiſhed the flame of a candle [*].

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[*] Mr. BERGMAN weighed fixed air after the manner commonly uſed to weigh common air. He found, from a mean of three experiments, that the weight of fixed air was to that of diſtilled water as $559\frac{1}{3}$ to one; the thermometer being about temperate, and the barometer at about a mean height.—De Acido Aëreo, ſect. 24.

[†] Exper. and Obſer. vol. i. p. 83

Fixed air is fatal to animals of every ſort. The age, healthineſs, and vigour of different animals, occaſions great diverſity in the times in which they are deprived of life by fixed air; thoſe animals, which breathe very little, living a longer time in it. Fiſhes die within a few minutes, in water impregnated with fixed air [†]. In general, it has been remarked, that the birds are killed in the leaſt time, next dogs, then cats, then the amphibious animals; and laſtly, the inſects live longer in it than any other ſpecies of animals [‡]. Sometimes an animal does irrecoverably loſe his life after one or two inſpirations of fixed air; however, in general, they become torpid, or loſe the ſtrength, and ſeem apparently dead, but revive in the open air, if they are taken out of the fixed air in a proper time; otherwiſe they die, but without ſtruggling. Animals, by being often confined in fixed air, and removed from it before they are killed, become in great meaſure habituated to that elaſtic fluid, ſo that they do not die in it as ſoon as other like animals which have not been uſed to ſuch experiments. The more common remarkable appearances obſervable in the bodies of thoſe animals that are killed by fixed air, are the following:—The lungs are found a little collapſed, ſhewing a few inflamed places. The right ventricle and right ear of the heart, the pulmonary artery, the *vena cava*, the jugulars, and the veſſels of the brain, are turgid with blood; whereas the pulmonary veins, the *aorta*, together with the left ventricle and left ear of the heart, are moſtly flaccid. The muſcular fibres of the body are found without irritability; ſo that even the heart, extracted whilſt the body is ſtill warm, ſhews no ſign of irritability *.

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[*] Phil. Tranſ. for 1766.

[†] Priestley's Exper. and Obſer. vol. ii. ſect. 13. N° 3.

[‡] Bergman de Acido Aëreo, ſect. 26.

Admitting Dr. Priestley's elegant theory of reſpiration, my reader muſt eaſily conceive, that the fixed air, being incapable of imbibing any phlogiſton, muſt occaſion the death of animals, inſomuch as the phlogiſton is accumulated on the lungs, &c.; but yet if we examine the various appearances attending this phenomenon, and the quickneſs with which an animal is affected (ſince moſt animals die ſooner in fixed air than in water) it appears, that the cauſe of death muſt be ſomething different from a mere retention of phlogiſton in the lungs. Some perſons have attributed it to a ſtimulus occaſioned by the fixed air, others have offered more intricate and leſs intelligible explanations; but, in truth, this matter ſtill remains to be inveſtigated.

Vegetable life is alſo deſtroyed by fixed air. Plants growing in full vigour, if introduced into receivers full of fixed air, periſh in a few hours time; nor are they recovered by being afterwards expoſed to the open air. Their ſtems and leaves generally become flaccid and blackiſh. "I took,"

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* Bergman *de Acido Aëreo*, ſect. 26.

ſays Dr. PRIESTLEY, " three other plants, and put one of " them into a jar of air of which *two thirds*, another into " one of which *one half*, and a third into one of which *one* " *fourth*, was fixed air. But to all appearance, all theſe " plants died as quickly as the two former had done (viz. *in* " *about one day's time)* which I believe was, in fact, almoſt " inſtantly; ſor the ceſſation of vegetable life muſt have " conſiderably preceded ſuch *viſible effects* of it as the black- " neſs and flaccid ſtate of the leaves and ſtalks *."

The Dr. found, that even a mixture of one eighth part fixed, and the reſt common air, was injurious to vegetation; plants gradually decaying, and within a few days periſhing in it †.—Water, impregnated with fixed air, is alſo noxious to the roots of plants ‡.

The colours of ſeveral flowers have been found to be little affected by fixed air, excepting the red colour of roſes, which is changed within a few hours time, by expoſure to fixed air. The change, as obſerved by Dr. PRIESTLEY, in ſome of his experiments, was gradually from red to blue, from blue to green, from green to yellow, and from yellow to a dirty orange-colour.

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* Exper. and Obſer. vol. iii. p. 311.

† Ibid.

‡ " But the many experiments, *ſays* Dr. PRIESTLEY, that I have made " ſince, in 1777 and 1778, have not left a ſhadow of doubt on my mind, that " ſuch water is hurtful, and finally fatal to the plants growing in it, at leaſt " to ſprigs of mint; for I did not make the trial with any other plants." Exper. and Obſer. vol. iv. p. 330.

Mr. Henry found, that fixed air can preſerve fruit incorrupt for a conſiderable time. He tried a bunch of Italian grapes, which being ſuſpended in the middle part of Dr. Nooth's apparatus, and being ſupplied with plentiful ſtreams of fixed air every day, was preſerved without any ſigns of decay for about one month longer than a ſimilar bunch ſuſpended in a decanter containing common air. Strawberries and cherries he alſo found to be preſerved without decay ſome days longer in fixed than in common air *. Indeed, fixed air preſerves not only fruit, but reſiſts putrefaction in general. Dr. Macbride, in his elegant Eſſays on Medical and Philoſophical Subjects, has publiſhed various experiments which demonſtrate this property of fixed air. He found, that not only good meat was preſerved incorrupt for a conſiderable time, when expoſed to fixed air, but that the putrefaction of ſubſtances actually putrid, was impeded by this means, and even that thoſe ſubſtances were reſtored from the putreſcent to a ſound ſtate †. That putrefaction was checked by fermentation, was diſcovered by *Sir* John Pringle; and Dr. Macbride obſerved, that this effect was owing to the fixed air produced in the act of fermentation. But it muſt be obſerved, that when the ſound, or even putrid ſubſtances, expoſe a very great ſurface to the fixed air, as is the caſe with milk, bile, and other fluids impregnated with fixed air, and alſo with ſmall bits of meat, then they are preſerved for a conſiderable time; but large pieces of ſolid animal ſubſtances, as for inſtance roundiſh pieces of fleſh of about half a pound weight, do not ſeem to remain incorrupt much longer in fixed than in common air; at leaſt the difference is inconſiderable. *Sir* WILLIAM LEE, baronet, in two of his letters to Dr. PRIESTLEY, informs him of his having found, that fleſh-meat, even in the hot ſeaſon, could be preſerved wholeſome for ſeveral days, by only waſhing it two or three times a day in water impregnated with fixed air; "we have been enabled," *ſays he*, "to preſerve meat as perfectly ſweet and good to "the extent of ten days, as at the firſt killing; and there "ſeems no doubt it might be preſerved much longer." He has even recovered ſome meat that had begun to change. This uſeful diſcovery, Sir WILLIAM juſtly obſerves, may be very beneficial to the public, eſpecially to butchers. "Par-"ticularly a butcher," *ſays he*, "who deals pretty largely, "aſſures me, he found the greateſt ſucceſs from it, and only "objects that the *veal* was a little diſcoloured, though kept "perfectly ſweet *."

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* Priestley's Exper. and Obſer. vol. iii. The Appendix, N° II.

† "By a mixture of fixed air, *ſays* Dr. Priestley, I have made wholeſome "the reſiduum of air, generated by putrefaction only, from mice plunged in "water."—Exper. and Obſer. vol. i. p. 101.

It is for its great property of hindering putrefaction, that fixed air by itſelf, or incorporated with various fluids, eſpecially with water; and that vegetables, ſugar, and other ſubſtances which abound with fixed air, are very powerful remedies in putrid diſeaſes. *Sir* JOHN PRINGLE ſuppoſes, with great probability, that the frequent uſe of ſugar and freſh vegetables, which at this time make up a conſiderable part of the diet of the European nations, prevents thoſe putrid diſeaſes and plagues which formerly were rather frequent. —Dr. MACBRIDE, ſhewing experimentally that fixed air is diſcharged by ſuch ſubſtances as form our common food, aſcribes the preſervation of the body from putrefaction in great meaſure to the fixed air, which in the ordinary proceſs of digeſtion is diſengaged from the aliment, and incorporates with the fluids of the body.

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* Appendix to the 4th vol. of Exper. and Obſer.

Metals being precipitated from their ſolutions by the addition of a mild alkali or calcareous earth, ſhews that the precipitation muſt be occaſioned by the fixed air of the alkali or calcareous ſubſtance joining with the metallic calx * ; but yet of the precipitation of a diſſolved metal by fixed air, when uſed in its elaſtic ſtate, I know of but one inſtance. It was Mr. HEY of Leeds who found, that in a ſolution of ſugar of lead a precipitation is occaſioned by expoſing fixed air to it.— This precipitate may be re-diſſolved by adding nitrous acid.

Fixed air precipitates the lime in lime-water, rendering it a calcareous earth, ſuch as it was before calcination; and that not only when the lime-water is expoſed to a body of fixed air, but alſo when water impregnated with fixed air is added to it. It is very remarkable, that if a quantity of fixed air, ſufficient to ſaturate the lime contained in a given quantity of lime-water, is expoſed to it, the lime will be precipitated; that is, the lime-water, loſing its tranſparency, becomes milky, and depoſits the particles of lime; but if, after this precipitation, more fixed air be expoſed to the ſame water, the precipitated lime will be re-diſſolved; but now it is contained in the water in the ſtate of calcareous earth, that is ſaturated with fixed air, and not in the ſtate of lime. This is owing to the property which water, impregnated with fixed air, has of diſſolving calcareous earth. Mr. CAVENDISH, who firſt obſerved this property, has ſhewn, in the Philoſophical Tranſactions for the years 1766 and 1767, that the calcareous earth contained in Rathbone-place water is kept diſſolved by the fixed air exiſting in it. Very probably, the ſuſpenſion of calcareous earth in various waters is owing to the preſence of fixed air; and the depoſition of the earthy matter, occaſioned in thoſe waters by boiling or long ſtanding, is owing to the eſcape of the fixed air, which is the menſtruum that kept it diſſolved.

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* Indeed, in this caſe, not only the fixed air combines with the metallic precipitate, but the earth of the calcareous ſubſtance or alkali combines at the ſame time with the menſtruum in which the metal is diſſolved; ſo that the precipitation is owing to both theſe cauſes; viz. a double combination.

Fixed air unites with the ſmoke of almoſt every ſubſtance; the ſmoke being retained in it, as we obſerved above of the ſmoke of a candle.

Fixed air requires ſome time before it mixes with common air, when they are expoſed to each other; ſo that if the lower part of a veſſel be filled with fixed, and the upper with common air, the fixed air, if not agitated, will remain at the bottom of the veſſel for ſeveral hours, though part of it does, even from the beginning, mix with the neareſt portion of common air *. But if this mixture of thoſe two elaſtic fluids, after being kept long together, be agitated in water, the fixed air is abſorbed and the common air remains.

Inflammable and fixed air ſeem to be not properly miſcible with each other; at leaſt, after long ſtanding together, they may be ſeparated by agitation in water. If the inflammable air is fired when fixed air is mixed with it, its flame acquires a blue colour: But of this we ſhall take notice in the next chapter.

Dr. PRIESTLEY having put together, by various combinations, in one veſſel, fixed, common, nitrous, and inflammable air, deduces from his experiments the following general concluſion; "that when two kinds of air have been mixed, "it is not poſſible to ſeparate them again, by any method "of *decanting*, or pouring them off, though the greateſt "poſſible care be taken in doing it. They may not proper-"ly *incorporate*, ſo as to form a *third ſpecies of air*, poſſeſſed "of new properties; but they will remain equally diffuſed "through the maſs of each other; and whether it be the "upper or the lower part of the air that is taken out of the "veſſel, without diſturbing the reſt, it will contain an equal "mixture of them both."

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* Exper. and Obſer. vol. i. p. 27. and vol. iii. p. 303.

And a little after he obſerves as follows: "Notwithſtanding
" theſe experiments, I do not ſay but that if two kinds
" of air, of very different ſpecific gravities, were put into
" the ſame veſſel, with very great care, without the leaſt
" agitation that might not mix or blend together, they
" might continue ſeparate, as with the ſame care *wine* and
" *water* may be made to do; but that, when once they
" have been mixed, they will continue to be ſo, like wine
" and water, after having been ſhaken together [*].

Dr. PRIESTLEY, having admitted fixed to alkaline air, obtained oblong and ſlender cryſtals, which, croſſing each other, covered the ſides of the veſſel with a kind of net-work [†]. It appears from his experiments, that half a meaſure of fixed air is ſufficient to ſaturate a whole meaſure of alkaline air [‡].

By mere expoſure, water imbibes fixed air, more or leſs readily according to the quantity of ſurface it expoſes to the fixed air. A pound of water, kept in ſuch a veſſel in which it may expoſe a ſurface of 20 ſquare inches to the fixed air, will become ſaturated with that elaſtic fluid in about ſix hours. It is evident, that agitation muſt furniſh the readieſt method of impregnating water with fixed air; ſince in that caſe the water expoſes a vaſt and continually new ſurface to the fixed air. Water, when agitated in fixed air, becomes fully ſaturated with it in about two minutes time.

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[*] Exper. and Obſer. vol. iii. ſect. 30.

[†] Ibid. vol. i. p. 171.

[‡] Ibid. vol. iii. p. 293.

It is alſo evident, that when water is expoſed to fixed air, it abſorbs unequal quantities of that elaſtic fluid in equal times, the quantities leſſening by degrees; viz. as the water becomes more and more impregnated with fixed air, ſo its attraction, or power of abſorbing it, gradually leſſens.

The preſſure of the atmoſphere aſſiſts conſiderably the retention of fixed air in water; and, in a condenſing engine, water may be impregnated with a much greater quantity of fixed air than under the uſual preſſure of the atmoſphere. And if water impregnated with fixed air be put under the receiver of an air-pump, the fixed air will eſcape from the water as ſoon as the air within the receiver begins to be exhauſted, the water appearing to boil. In ſhort, water cannot remain impregnated with fixed air in vacuo *.—The eſcape of the fixed air is the cauſe of the boiling of ſeveral liquors, as beer, Pyrmont water, &c. that abound with it, when under an exhauſted receiver †.

Under the uſual preſſure of the atmoſphere, and in a temperate degree of heat, water can abſorb a quantity of fixed air equal to its own bulk, or very little more.

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* Mineral waters retain the fixed air more obſtinately than common water artificially impregnated with fixed air; which is owing to ſome other principle or principles contained in the mineral water; perhaps to earthy particles and metals.

† If water impregnated with fixed air, inſtead of being kept in veſſels cloſe ſtopped, be expoſed to the open air, the fixed air will eſcape from it in the courſe of ſome hours. Mr. Hey obſerved, that if water tinged blue with the juce of tourneſole, and then turned red by impregnating it with fixed air, be expoſed to the open air, it recovers the blue colour again.

Cold alſo enables the water to abſorb more fixed air, and, on the contrary, heat leſſens that power. The heat of boiling water expels all the fixed air that is artificially combined with it; but, in order to expel every particle of fixed air from water, the water artificially impregnated with it muſt be boiled for about half an hour, and the mineral waters muſt be boiled for at leaſt two hours. Although water will abſorb more fixed air when cold than when hot, yet ice will not imbibe any of it, and water impregnated with fixed air, yields all its fixed air the moment it becomes ice. Upon the whole, it appears that water can abſorb the greateſt quantity of fixed air, when it is agitated with it, under the heavieſt atmoſpherical preſſure, and when coldeſt, except it freezes.

When fixed air is agitated in water, even when the latter is many times greater in bulk than the former, a ſmall portion of the fixed air remains always unabſorbed. This reſiduum, when the pureſt fixed air is uſed, generally amounts to the ſixtieth part of its bulk. The nature of this reſiduum is quite different from that of fixed air; Dr. PRIESTLEY having found it to be of the nature of common air a little phlogiſticated. "A mouſe," *ſays he*, "will live very well, though "a candle will not burn, in the reſiduum of the pureſt fixed "air that I can make [*]."

Dr. PRIESTLEY ſaturated a quantity of water with fixed air, a reſiduum remaining as uſual, and expelled it again;

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[*] Exper. and Obſer. vol. i. p. 40.

then agitating this expelled fixed air again in other water, found that about the ſixtieth part of it remained ſtill unabſorbed. The Doctor repeated the experiment with every poſſible precaution; viz. uſed water that had been boiled for above two hours; began to impregnate it with fixed air whilſt it was yet hot, leſt it might have imbibed ſome air from the atmoſphere, &c.; but it was attended with the ſame reſult. In explanation of this remarkable phenomenon, Dr. PRIESTLEY offers the following ingenious conſideration:—"Fixed air, phlogiſticated with iron-filings and "brimſtone, or with the electric ſpark, I have diſcovered, "vol. i. p. 42, to become, in a much greater proportion "than uſual, immiſcible with water; and I therefore con-"cluded, that this acid air (for ſuch fixed air evidently is) "by combining with phlogiſton, comes to be a kind of "air ſimilar to common air. If this be a juſt account of "the former experiment, the fixed air, in this caſe, muſt get "phlogiſton from the water with which it was combined, "and thereby become, in part, immiſcible with water*.

Water, by being impregnated with fixed air, acquires the following properties, viz. its ſpecific gravity is increaſed; and in a temperature of 71° of Farenheit's thermometer, Mr. LAVOISIER found, that the ſpecific gravity of diſtilled water is to the ſpecific gravity of diſtilled water impregnated with fixed air, as 1,000,000 to 1,000,332 †. Mr. BERGMAN

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[*] Exper. and Obſer. vol. ii. p. 221.

[†] Eſſays Phyſical and Chemical, p. 247.

found, that in a temperature anſwering to about the 3½ deg. of Farenheit's, the weights of equal quantities of diſtilled water, and diſtilled water impregnated with fixed air, were to each other as 1,000 to 1,0015 [*].

The impregnation of fixed air communicates to water a kind of ſubacid taſte, like the taſte of ſome mineral waters called *acidulous* [†]. Beſides the ſubacid taſte, the acidulous mineral waters taſte, in ſome meaſure, different from water artificially impregnated with fixed air, which ſhews that ſomething elſe beſides fixed air contributes to the taſte of the former. But by adding bits of iron to water impregnated with fixed air, part of the metal is ſoon diſſolved, and then the taſte and ſmell of this water becomes very ſimilar to that of the mineral chalybeate or acidulous waters. Thus an artificial chalybeate water may be made, which may be conſidered to be ſuperior to the natural for medicinal purpoſes; ſince by art the water may be impregnated with more fixed air than Pyrmont water has been found to contain [‡].

That water impregnated with fixed air diſſolves iron, was diſcovered by Mr. LANE; but Mr. BERGMAN remarked various curious particulars relating to it. Having put a quantity of iron filings into water impregnated with fixed air, he kept the veſſel that contained it in a cold place during twenty-four hours; after which time he found, that part of the metal had been diſſolved. When this water was expoſed to the open air, a film of very minute metallic particles, which reflected various colours, was formed upon it. The weight of the whole of this metallic depoſition was found to be equivalent to $\frac{1}{10,500}$ part of the weight of the water.

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[*] De Acido Aëreo. ſect. 4.

[†] The diſagreeable taſte of diſtilled water is not removed by impregnating the water with fixed air. PRIESTLEY's Exper. and Obſer. vol. ii. p. 287.

[‡] Dr. BROWNRIGG, examining the Pyrmont water at the ſpring's head, never found it to contain ſo much as one half of an equal bulk of air.

It was ſo far in a metallic ſtate, that it was attracted by a magnet, and was ſoluble in the mineral acids *. This great Chymiſt found, that water impregnated with fixed air diſſolves zinc, in the metallic as well as in the calcined ſtate, and alſo manganeſe and its regulus †.

Theſe three are the only metallic ſubſtances that have been found diſſoluble in water impregnated with fixed air; and it is very remarkable, that fixed air will not attack any of them when in the form of an elaſtic fluid uncombined with water.

Various other ſubſtances are diſſoluble in water thus impregnated; as ſmall portions of chalk, and in general of all calcareous earths, of human calculus, of magneſia, and of ſome other mixed earthy ſubſtances.

It is ſaid by Dr. Priestley, in his Experiments and Obſervations,

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[*] Mr. Rovelle found, that water impregnated with fixed air could even diſſolve ſome of the calciform ores of iron.

[†] By diſſolving this regulus in it, the impregnated water acquires a peculiar odour, much like that of burned fat. De Acido Aëreo.

ſervations, vol. i. p. 31, that diſtilled water, impregnated with fixed air, does not mix with ſoap ſo readily as diſtilled water by itſelf; but I remember, that ſome time ago, having repeated this experiment with Mr. FONTANA, we did not obſerve any difference; the ſoap ſeeming to have been diſſolved with equal facility, and in equal quantity, both in the impregnated as in the unimpregnated water.

A few years ago, Mr. ACHARD publiſhed, in the *Journal de Phyſique*, his having made true *cryſtals* of the ſame ſhape and hardneſs as the native rock cryſtals, by a ſlow filtration of water after a certain manner impregnated with fixed air. I need not detain my reader with an account of Mr. ACHARD's apparatus and method of proceeding, ſince the veracity of his diſcovery has been juſtly queſtioned, after that upon accurate trial no ſuch thing could be produced in England, nor, as far as I am informed, by any body elſe abroad; and, upon the whole, the thing ſeems to be very unlikely to happen.

Fixed air, as it is combined with water, ſo may it be combined with other liquors. Beer, wine, and other fermented liquors, may be impregnated with fixed air, and by this means their ſharpneſs may be reſtored, when they are become vapid, or, as it is commonly ſaid, *dead*[*]. Milk acquires an acidulous taſte by being impregnated with fixed air, and is thereby preſerved incorrupt for ſome days; which affords a very eaſy expedient of preſerving milk, in thoſe places where it cannot be had new very often. Milk parts with the imbibed fixed air very difficultly, requiring many hours boiling. Saliva has been found, by Mr. HENRY, to abſorb three times its bulk of fixed air. Spirit of wine was found, by Mr. CAVENDISH, to abſorb 2 ÷ its bulk of fixed air, the thermometer being at 46 degrees.

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[*] The acidulous taſte communicated by the impregnation of fixed air, cannot be diſcovered in beer, wines, and, in ſhort, in ſuch liquors which have much taſte of their own.

I ſhall here add Mr. BERGMAN's liſt of the affinities of fixed air, and then ſhall conclude this chapter with an account of the medicinal properties of this permanently elaſtic fluid.

Fixed air has affinity with the following ſubſtances, and in the order in which they are ſet *.

Pure ponderous earth.
Pure lime.
Pure fixed vegetable alkali.
Pure fixed mineral alkali.
Pure magneſia.
Pure volatile alkali.
Zinc.
Manganeſe, and
Iron.

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* De Acido Aëreo.

With reſpect to the other acids, fixed air appears to be the weakeſt of them all, ſince it may be expelled by any other acid.

Before it was diſcovered that the acidulous taſte of certain mineral waters was occaſioned by the fixed air, thoſe waters, and alſo certain fermented liquors, which contain much fixed air, were recommended for ſeveral diſorders incident to the human body. But it has been lately diſcovered, that the medicinal effects of thoſe liquors were owing to the fixed air contained in them; hence it has been juſtly recommended by Dr. PRIESTLEY and others, to uſe water impregnated with fixed air, inſtead of thoſe naturally acidulous waters; becauſe, with a portable apparatus, the water artificially impregnated with fixed air, may be made in any place, and a much greater quantity of fixed air may be combined with it, than does commonly exiſt in the mineral waters *. —This new remedy added to the *materia medica*, ſince it was firſt recommended, has been uſed with great, though not with univerſal good ſucceſs. Indeed I do not hear that the uſe of it was ever attended with any bad conſequences; and it appears, that ſeveral caſes, in which the application of fixed air has not produced any good effect, were of a very deſperate nature. The remarkable cures indiſputably effected by the uſe of fixed air, eſtabliſh its reputation beyond any doubt, and only leave to find out the extent of its power, viz. the variety of diſeaſes for which it may be uſed, and to contrive a greater variety of ways to adminiſter it with facility and certainty in different caſes.

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* Here it is not meant to aſſert, that the artificial acidulous water ſhould be recommended in preference to any mineral waters, but only in preference to thoſe mineral waters which are ſuppoſed to contain only fixed air, or to be uſed only on account of the fixed air they may contain.—The effects of mineral waters are more commonly owing to other ſubſtances contained in thoſe waters, than to the fixed air, of which moſt of them contain but an inconſiderable quantity. That by mixing fixed air, and ſeveral other ſubſtances, ſome mineral waters may be imitated, is not only probable, but has been actually done: But this is foreign to my ſubject.

Fixed air has been applied by itſelf, but more commonly combined with other ſubſtances, eſpecially with water.—The diſeaſes against which it has proved beneficial, are principally thoſe of a putrid nature: The *ſcurvy*, *malignant fevers*, *ulcers*, *cancers*, *ſore-throat*, *malignant ſmall-pox*, the *ſtone of the bladder*, and *calculous concretions*.

Fixed air by itſelf, viz. in an elaſtic ſtate, has been applied, I. Externally, by expoſing a particular part of the body to the mouth of a veſſel which contained the proper materials for the production of fixed air. Sometimes a glaſs or wooden veſſel, like a common funnel, or otherwiſe ſhaped, ſo as to be conformable to the ſurface of that part of the body to which the fixed air was required to be applied, has been faſtened to a bladder containing fixed air, and then, gently preſſing the aperture of the veſſel, &c. upon the required part of the body, the fixed air has been thrown upon it by ſqueezing the bladder [*]. II. *Internally*, by letting the patient breathe over the mouth of a veſſel out of which the fixed air iſſues, in order to convey it into the lungs.—This muſt be done with great moderation. And by way of *clyſters* [‡]. In this caſe no diſtenſion of the inteſtines ſhould be apprehended, ſince fixed air is eaſily abſorbed by the fluids of the body, provided care be taken that the leaſt poſſible quantity of common air is mixed with it.

The more common application of fixed air has been by combining it with ſome other ſubſtance, moſtly water, and then letting the patient drink it, or waſhing ſome particular part of the body with it.—In the ſecond part of this treatiſe, p. 304, we deſcribed Dr. NOOTH's apparatus for impregnating water with fixed air; but here it is proper to add a few practical remarks relating to the uſe of it.

Powder of marble may be uſed for the production of fixed air in this apparatus, in preference to chalk, only becauſe it yields fixed air for a long time, whereas chalk gives a great quantity of it in a ſhort time.

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[*] "It is even poſſible," *ſays* Dr. PRIESTLEY, "that a conſiderable quantity of fixed air might be imbibed by the abſorbing veſſels of the ſkin, if "the whole body, except the head, ſhould be ſuſpended over a veſſel of "ſtrongly fermenting liquor; and in ſome putrid diſorders, this treatment "might be very ſalutary." Exper. and Obſer. vol. i. p. 103.

[‡] For this purpoſe the fixed air muſt be firſt introduced into a bladder See p. 264 of this treatiſe.

[†] Sometimes the powder of marble, without adding any freſh acid, will continue to yield fixed air for ſeveral days together.

When the apparatus is to be ſet to work, the powder of marble is firſt put into the lower veſſel, together with the diluted oil of vitriol, and then the middle veſſel full of water is put upon it; and laſtly, the uppermoſt veſſel, without any water in it, is put in its place.

During the efferveſcence, the fixed air riſes into the middle veſſel, and reſts upon the ſurface of the water; part of which, being diſplaced, will riſe into the uppermoſt veſſel. If the apparatus is not moved, the water will be fully impregnated in about four or five hours time; but by gently agitating now and then the apparatus, the production of fixed air, as well as the impregnation of the water, is greatly promoted.

When the impregnated water is drawn out of the middle veſſel, more freſh water muſt be poured into the upper veſſel.

After the ſame manner, milk, and other liquors uſually given to patients, may be impregnated with fixed air, in thoſe caſes which ſeem to require it.

The ingenious Mr. Bewly, finding that mild fixed alkali is capable of combining with a vaſt quantity of fixed air, as we have already taken notice of, juſtly conſiders this impregnated ſalt to be probably of great uſe in medicine, "in "putrid diſeaſes particularly, and in all thoſe caſes where "we would wiſh to introduce a larger quantity of fixed air "into the ſyſtem, than can be condenſed by, or combined "with, ſimple water. By previouſly diſſolving in this fluid

" certain quantities of fixed alkaline ſalt, it may be made to " receive twice or thrice its bulk, or a ſtill larger proportion, " of fixed air *.

The ſcurvy, when juſt beginning, has been commonly cured by the uſe of water impregnated with fixed air; but when the diſorder has been far advanced, the uſe of it has ſeldom proved beneficial; though there are ſome indiſputable caſes of this ſort, in which the cure was evidently effected by the fixed air. In thoſe caſes may be uſed, either the water impregnated with fixed air, as firſt ſuggeſted by Dr. PRIESTLEY, or the infuſion of malt, that is, ſweet-wort, as recommended by Dr. MACBRIDE. The patient may drink freely of it †.—Dr. HULME recommends the following method of adminiſtering fixed air:—" Take," *ſays he*, " of pure ſalt of tartar " one ounce (troy weight) diſſolve it in ſixteen ounces of " common water, and call it the *alkaline mixture*. Alſo, " take of weak ſpirit of vitriol two ounces meaſure, of com- " mon water fourteen ounces, ſo as to make in the whole " ſixteen ounces, to be called the acid mixture.

" Let the patient take half an ounce meaſure of the *alka-* " *line mixture*, in three ounces of common water, four times " a day; and immediately afterwards, let him take half an " ounce of the *acid mixture*, in the ſame quantity of water;

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[*] Exper. and Obſer. vol. ii. p. 356.

[†] Although the apparatus for impregnating water with fixed air is very portable, yet for ſea-voyages the uſe of malt may perhaps be preferred. This ſubſtance, when well dried, may be kept many years.

" and continue theſe medicines till the ſcorbutic ſymptom " diſappear, &c. If occaſion ſhould require, the doſe may " be increaſed to double the quantity."

In putrid malignant fevers, and in ſeveral very alarming caſes, in which every other remedy had been applied in vain, the uſe of fixed air has performed a ſpeedy and perfect cure. Indeed, the caſes of this ſort, in which the proper application of fixed air has proved unſucceſsful, are very few; ſo that it ſeems rather ſtrange, that fixed air is not more generally uſed in thoſe diſorders.—In caſes of this ſort, the patient is made to drink freely the impregnated water, or other liquors abounding with fixed air; and alſo clyſters of fixed air are adminiſtered unto him.

In regard to the pulmonary conſumption, Dr. PERCIVAL, in his Eſſays Medical and Experimental, ſays, that having tried fixed air in more than thirty caſes, the hectic fever was, in many inſtances, abated, and the expectorated matter became leſs offenſive; but he could never cure one patient *. But others, as Dr. WITHERING, Dr. HULME, and Dr. DOBSON, have been more ſucceſsful; ſome patients of this ſort having been intirely cured by them.

" If mephitic air," *ſays* Dr. PERCIVAL, " be thus capable " of correcting purulent matter in the lungs, we may reaſon" ably infer it will be equally uſeful when applied externally

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* He remarks, that fixed air may, in no inconſiderable quantity, be breathed without danger or uneaſineſs.

" to *foul ulcers.* And experience confirms the concluſion. " Even the ſanies of a *cancer*, when the carrot poultice failed, " has been ſweetened by it, the pain mitigated, and a better " digeſtion produced *."

In caſes of the *ulcerous ſore-throat*, great benefit has been received by drawing the fixed air into the *fauces.*

In caſes of the ſtone in the bladder, fixed air has often afforded ſingular benefit. It is remarkable, that before any thing was known of the properties of fixed air, ſeveral liquors, which have been afterwards found to contain abundance of fixed air, were often recommended for the ſtone in the bladder. I remember to have read them recommended in ſome old medical books.

Dr. PRIESTLEY has proved, that fixed air, detached from our aliments, is conveyed by the courſe of circulation into the urine, and is expelled with it; for, by means of heat, he has extracted fixed air from freſh-made urine. And he obſerves, that after the proceſs, a conſiderable whitiſh ſediment was found at the bottom of the veſſel. " This," *ſays he*, " was probably ſome calcareous matter with which the fixed " air had been united; and by this fixed air the calcareous " matter, which would otherwiſe have formed a ſtone or " gravel, may have been held in ſolution:" from which he juſtly infers, that by drinking water impregnated with fixed air, the ſtone in the bladder may be diſſolved, &c *. This inference was afterwards experimentally proved by Dr. PERCIVAL. See Exper. and Obſer. vol. ii. p. 368. Not only the water impregnated with fixed air after the uſual manner, but other preparations productive of fixed air, have been alſo uſed. Dr. HULME recommends his above-mentioned mixture. Dr. DOBSON gives the following directions:—" Let the patient " take, three times a day, an ounce of the *aqua mephitica* " *alkalina*, containing one ſcruple of alkaline ſalt, ſaturated " with fixed air according to the directions of Mr. BEWLY, " and ſweetened with a little honey: let him waſh this " down with half an ounce or a large ſpoonful of lemon-" juice, made into lemonade †."

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* PRIESTLEY's Exper. and Obſer. vol. ii. Appendix, N° 3.

It muſt be obſerved, that whenever fixed air is uſed in any diſeaſe, the other uſual medicines muſt not be omitted; at leaſt hitherto it has been given at the ſame time that other medicines were adminiſtered.

I ſhall now add a few phyſical caſes, in which fixed air has been adminiſtered with good ſucceſs, referring at the ſame time

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[*] Exper. and Obſer. vol. ii. p. 217; and in p. 361 of the ſame vol. Dr. PERCIVAL, in a letter to Dr. PRIESTLEY, obſerves as follows: " I have found, by " repeated trials, that *calculi*, extracted from different ſubjects, and varying in " ſize, figure, and texture, are ſoluble in water impregnated with fixed air; that " this menſtruum is more powerful in its operation even than lime-water; " and that though it is inferior in efficacy to the vitriolic acid, and the cauſtic " alkali, yet it is more univerſal in its action than either of them."

[†] Medical Commentary on Fixed Air, p. 145.

time thoſe readers, who are deſirous of reading farther accounts of ſimilar caſes, to the writings of other authors †.

CASE I. *Related by* Dr. Dobson, *in his Commentary of Fixed Air.*

" Fuller Turkey, about forty years of age, was made an " out-patient of the hoſpital, November 25th, 1773. He " was a ſailor, and had been cruelly treated nine or ten " months before, when out at ſea. He was thrown down, " and received ſuch violent blows, when in this ſituation, " that ſeveral of the ribs on the right ſide were broken, and " the lungs much injured. The conſequence of which was, " that he had great pain in the ſide, a very painful cough, " and ſpit blood frequently, and in large quantities. When " I firſt ſaw him, the *hæmoptoe* had ceaſed, but the cough " and pain were worſe, the reſpiration very difficult, the " breath very offenſive, with a copious expectoration of " purulent matter, night-ſweats, and the pulſe from 120 " to 130.

" Bleeding in ſmall quantities, emetics, anodynes, demulcents, had not the leaſt power to check the progreſs of " the diſeaſe; ſo that by December the fourth he was become extremely weak, and not able to quit his bed; the " reſpiration ſtill more difficult and ſuffocating, the breath

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† The Appendixes to Dr. Priestley's vol. of Exper. and Obſer.; the Eſſays of Dr. Macbride, and thoſe of Dr. Percival; Dr. Dobson's Commentary on Fixed Air; &c.

" ſo offenſive as to taint the whole room, and the pulſe ſtill " more frequent.

" He was now directed to receive into the lungs the " fixed air of chalk, detached by the acid of vitriol, and to " take the ſalt of tartar and lemon-juice in the ſtate of effer- " veſcence three times a day. In ſeven days, the cough was " more moderate, the reſpiration eaſier, the ſpitting, hectic, " and night-ſweats diminiſhed, and the breath not at all of- " fenſive. In four weeks more, he had gotten ſtrength and " fleſh, and was free from his pulmonic affections."

CASE II. *By the ſame*

" About the ſame time with the above patient, a young " gentleman was under my care, on account of an abſceſs in " the right lobe of the lungs.

" There were repeated collections of matter, and repeated " ruptures, with great diſcharges of blood as well as pus. " The breath was intolerably offenſive, and the cough very " painful and troubleſome, with hectic and ſweats.

" This patient recovered, and received evident benefit " from the efferveſcing draughts, and the inſpiration of " fixed air."

CASE III. *By the ſame.*

" Ann Forbes, ſervant to Mr. Hume, of York-ſtreet, " Liverpool, had the *confluent ſmall-pox*, in Auguſt 1773. " The weather was extremely hot, and the ſymptoms ſo

" very unfavourable, that there did not appear the moſt diſ-
" tant hope of her recovery. Particular care was taken to
" have a conſtant ſupply of freſh air; and the antiphlogiſtic
" treatment was ſtrictly purſued during the inflammatory
" fever. The diſeaſe was now advancing into the putrid
" ſtage; and the ſecond fever commenced with little or no
" appearance of ſuppuration.

" Notwithſtanding every precaution with reſpect to the
" free acceſs of air, change of linen, and every circumſtance
" of cleanlineſs, the unlimited uſe of oranges, lemonade,
" and wine negus, this poor creature was the moſt miſer-
" able object I ever beheld. She became extremely offenſive,
" and had the appearance of one continued maſs of *putrid*
" *ichor*; the pulſe ſmall and rapid; and ſhe had a conſtant
" reſtleſſneſs, with inexpreſſible anxiety.

" A purgative was directed, and a glaſs of ſweet mountain
" after every ſtool. The ſymptoms, however, became more
" alarming, the offenſiveneſs was almoſt intolerable, and ſhe was
" frequently ſick, agitated, trembling, and like one about to
" expire. In this urgent ſituation I determined to try the
" effects of fixed air; and it was given in the manner already
" mentioned.

" The nurſe and attendants ſoon obſerved an agreeable
" change. In twenty-four hours the putrid ſtench was much
" diminiſhed, the breath of the patient was not near ſo of-
" fenſive, and the chamber was very tolerable, compared
" with what it had hitherto been. In two days more, ſhe

" was ſtill much better; and, by repeating the purgative, " giving wine occaſionally, and perſevering in the uſe of " fixed air, her recovery was ſurpriſingly ſpeedy and per- " fect.

" When the patient has been ſo young as to render it im- " practicable to give ſalt of tartar and lemon-juice, I have " directed the naked body to be held over an effervefcing " mixture, or a ſtream of fixed air to be applied ſucceſſively " to different parts of the body; and by the uſe of theſe " means, have found the putrid ſymptoms powerfully cor- " rected."

CASE IV. *Related by* Dr. J. Warren *.

" Mr. C——, aged twenty-three, a gentleman of great " temperance, and of a good conſtitution, laboured under " an irregular nervous fever for the ſpace of ten weeks, at- " tended for the moſt part with delirium, and almoſt con- " ſtant watchfulneſs.

" At the expiration of this period, ſymptoms of putridity " began to make their appearance; ſeemingly, however, " more owing to emaciation, and to the long continuance of " his diſeaſe, than to any original contagion. The Peruvian " bark had, from time to time, particularly during the latter " ſtages of his illneſs, been adminiſtered to him, which, on " the appearance of putrefactive ſymptoms, was increaſed

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* Priestley's Exper. and Obſer. vol. ii. p. 377.

" to the quantity of two ſcruples, given in the form of bolus, with thirty drops of elixir of vitriol, every two hours. " Every thing he drank was acidulated with the juice of lemons or oranges; and his common liquor was Port wine " mixed with Pyrmont water. This courſe was perſiſted in for " ſome days; the putrid complaints, however, increaſed; " and ſo great was the fœtor emitted with his breath, and " ariſing from his body, that, notwithſtanding his being ſupplied with a conſtant ſucceſſion of freſh air, and though " large quantities of vinegar, lavender-water, and rue, with " other odoriferous ſubſtances, were conſtantly made uſe of " to purify his room, yet all were found perfectly ineffectual. His ſtools, which at this period conſiſted of little elſe " than putrid blood, and which came from him in great " abundance (in the whole to the amount of many pounds) " were abſolutely intolerable; nor was it without much " difficulty that the nurſes could be induced to remain any " longer near him.

" Univerſal languors, with almoſt total inſenſibility, now " ſupervened: an earthy coldneſs diffuſed itſelf through every " part of his body; nor were the hotteſt fomentations, " though continued three hours together, capable of procuring him any degree of warmth.—Every breath he drew " ſeemed to be his laſt.—In this deplorable ſituation he continued a whole day; his boluſſes were omitted through " neceſſity; and with difficulty we could, from time to time,

" get him to ſwallow a few ſpoonfuls of ſome warm cordial " medicine; which, however, by continually repeating, began at length, in ſome degree, a little to revive him.

" I now ordered him clyſters of *fixed air*, of which a large " bladder-full, containing near two quarts of air, was every " three or four hours injected; and his bark boluſſes were " again given to him as often as his ſtomach would allow " him to take them. In the ſpace of eighteen hours, the " cadaverous fœtor ariſing from him began to abate; large " vibices, or putrid blotches, were now, for the firſt time, " diſcovered on almoſt every part of his body: his pulſe, " however, was better, and his warmth in ſome little degree " returned: the boluſſes and clyſters were ordered to be " continued. In four or five days the noiſome ſmell became " imperceptible, the vibices gradually diminiſhed, and his " fever left him. He is now perfectly recovered, and a " living miracle of what fixed air, under Divine Providence, " is capable of effecting on the human œconomy, in caſes of " the worſt and moſt putrefactive nature."

CHAP. IV.

Of inflammable Air.

THE permanently elaſtic fluid called *inflammable air*, or *inflammable gas*, is, like fixed air, both the production of natural and of artificial proceſſes. It being abundantly produced by putrid animal and vegetable ſubſtances, and, in general, by thoſe inflammable ſubſtances, the phlogiſton of which is eaſily ſeparable from them; it follows, that in all thoſe places in which like proceſſes are continually going on, there the inflammable gas is produced; hence, in caverns and mines, eſpecially coal-mines, this elaſtic fluid is often found; ſometimes, on breaking ſome pieces of the minerals in the mines, which probably diſcloſes ſome hidden cavity, the inflammable gas ruſhes immediately out. As this is ſpecifically lighter than common air, it always aſcends in it; ſo that it is not confined in the mines, except in ſome vaulted part of thoſe ſubterranean places; for otherwiſe, as ſoon as it comes out of the fiſſures, &c. it aſcends upwards and mixes with the atmoſpherical air.

This gas, being generally found mixed with much common air, is not ſo noxious to the miners as fixed air is, and in that mixed ſtate people may breathe it with impunity; but being inflammable, renders it very dangerous to bring any lights in thoſe places, and even to ſtrike a flint with ſteel;

the ſparks ariſing from it being often ſufficient to fire it. Sometimes it happens, that the inflammable air in mines takes fire, and then it explodes with great danger to the by-ſtanders, who are ſometimes inſtantly killed by it. From this property of taking fire, and exploding, the miners, who have long been acquainted with this gas, call it the *fire-damp*.

Beſides thoſe ſubterranean places, inflammable air is often found in ditches, over the ſurface of putrid water, out of which it eſcapes; in burying-places, houſes of office, where putrid vegetable or animal ſubſtances are accumulated; and may, by ſtanding or by boiling, be extracted from the waters of moſt lakes and rivers, eſpecially thoſe wherein much fermentable and putrefying matters are waſhed, as of the Thames, the Severn, &c.

It is hardly worth mentioning, that a greater abundance of inflammable air muſt be thus naturally produced in warmer than in colder climates, ſince heat, accelerating fermentation and putrefaction, muſt evidently contribute to the quick and abundant production of this elaſtic fluid.

In all the ponds about London, eſpecially in the ſummer and autumn, inflammable air may be catched very plentifully. The method is as follows:—Fill a wide-mouthed bottle with the water of the pond, and keep it inverted therein, then with a ſtick ſtir the mud at the bottom of the pond, juſt under the inverted bottle, ſo as to let the bubbles of air which come out of it enter into the bottle; which air is inflammable. When by thus ſtirring the mud in various places, and catching the air in the bottle until this is filled, a cork or glaſs-ſtopper muſt be put over it, whilſt ſtanding in water, and then the bottle may be taken home, in order to examine the contained inflammable fluid at leiſure.

In hot climates, if the mud at the bottom of a pond is well ſtirred, and immediately after a lighted candle is approached to the ſurface of the water, the inflammable air taking fire, a flame will be inſtantly ſpread over the ſurface of the pond, affording a very curious ſpectacle in the night-time *.

Several meteors ſeen in the atmoſphere have been ſuſpected to be the effects of inflammable air fired by electricity. The weak lightnings, without any exploſion, that are ſometimes obſerved near the horizon in ſerene weather, eſpecially in hot climates, are conſidered, by a very judicious philoſopher, to be nothing more than inflammable air detached from the earth by the heat, &c. and fired by electricity, or by ſome other unknown cauſe. Mr. VOLTA of Como ſuppoſes, that the *ignes fatui* are occaſioned by the inflammable air which proceeds from marſhy grounds, and is ſet on fire by electric ſparks. Thoſe meteors commonly called *falling ſtars*, he ſuppoſes to be fired by the ſame means.—That the atmoſphere is always, or at leaſt moſtly, electrified, there is no doubt; but the preſent knowledge of electricity does not enable us eaſily to conceive how any electric ſparks may happen in the ſerene atmoſphere, capable to fire inflammable air.

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* See a letter of Dr. Franklin's, in Dr. Prieſtley's Exper. and Obſer. vol. i. p. 321.

Inflammable and fixed air, and alſo phlogiſticated air, are diſcharged by our aliments in the natural courſe of digeſtion, and are expelled from the inteſtines through the mouth or otherwiſe.

Vanhelmont, in his treatiſe *de flatibus*, ſect. 49, ſays, " *Quod ructus, ſive flatus originalis in ſtomacho, prout et flatus ibi, extinguant flammam candelæ. Stercoreus autem flatus, qui in ultimis formatur inteſtinis, atque per anum erumpit, tranſmiſſus per flammam candelæ, tranſvolando accenditur, ac flammam diverſicolorem, iridis inſtar exprimit.*"

There is, perhaps, no inflammable ſubſtance upon earth, out of which, either by heat, or by fermentation, or by menſtruums, ſome inflammable air cannot be obtained. But to the inflammable elaſtic fluids thus obtained from various ſubſtances, and by various proceſſes, perhaps no other common properties can be attributed beſides thoſe of being inflammable, and of being ſpecifically lighter than common air. For the reſt, they ſhew material difference between each other. The ſmell, weight, power of burning, of preſerving their properties, and the phenomena attending their combuſtion, are not conſtantly the ſame in all the various ſpecimens of inflammable air. Inſtead, therefore, of underſtanding this ſort of elaſtic fluid under the name of inflammable gas, its various ſpecies might be more properly conſidered to be diſtinct ſubſtances, arrangeable, on account of their common property, under the generic name of *inflammable gaſes.*— For the preſent, neglecting their diſtinctions, we ſhall take notice of the various artificial methods of obtaining an inflammable fluid, permanently elaſtic and inviſible, like common air. It is, however, neceſſary to remark a proper diſtinction between an inflammable elaſtic fluid, or inflammable gas, which may be properly called ſo, and that which is evidently made by combining an inflammable ſubſtance with common air, which being eaſily ſeparable from the air, leaves that reſpirable fluid in the ſtate it was before. Thus a drop of ether, put in a quantity of common air, mixes itſelf with it, and takes fire at the approach of flame, like a mixture of inflammable and common air *; but if the air, to which the ether has been added, is waſhed in water, the ether is ſoon ſeparated from it. I am aware that this diſtinction does not admit of very perſpicuous limits; and it is probable that hereafter may be diſcovered, that every kind of inflammable gas is a mixture of common air with a ſulphur, or with ſomething elſe; but yet it is proper to avoid, as far as it is poſſible, any confuſion of ideas.

Heat alone is capable to extract a good deal of inflammable air out of moſt inflammable ſubſtances, even from ſome of

* Mr. CIGNA obſerves, that air ſaturated with volatile alkali is inflammable; and Dr. PRIESTLEY found that alkaline air was inflammable. The inflammation occaſioned by approaching a light to the famous plant called *froxinella*, is owing to its eſſential oil, which, mixing with the air about it, in calm and hot weather, renders it inflammable.

Were it pure inflammable air, it would, on account of its ſpecific gravity, leave the plant as ſoon as it was produced.—By being tranſmitted through ſeveral eſſential oils, common air acquires the property of being inflammable.

the metals. Dr. HALES obtained inflammable air by ſimply diſtilling wax, pitch, peaſe, amber, coals, and oyſter-ſhells *. But Dr. PRIESTLEY has obtained it from a vaſt many more ſubſtances. His method is, to introduce the required ſubſtance into a gun-barrel, to the extremity of which a tube of glaſs, or of a tobacco-pipe, was luted, and a flaccid bladder was tied to the end of this tube, which received the elaſtic fluid produced, when the gun-barrel was put into the fire. The Doctor obſerves, that in order to get a conſiderable quantity of inflammable air from various ſubſtances, the heat muſt be applied ſuddenly. "For," *ſays he*, "notwithſtand-" ing the ſame care be taken in luting, and in every other " reſpect, ſix or even ten times more air may be got by a " ſudden heat than by a ſlow one, though the heat " that is laſt applied be as intenſe as that which was ap-" plied ſuddenly. A bit of dry oak, weighing about twelve " grains, will generally yield about a ſheep's bladder full of " inflammable air with a briſk heat, when it will only give " about two or three ounce meaſures, if the ſame heat be " applied to it very gradually. To what this difference is " owing, I cannot tell. Perhaps the phlogiſton, being ex-" tricated more ſlowly, may not be entirely expelled, but " form another kind of union with its baſe †." When the

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* Mr. FONTANA ſays to have extracted a conſiderable quantity of inflammable air from ſpathoſe iron, by the action of fire only, applied to a matraſs. —Phil. Tranſ. vol. lxix. p. 360.

† Exper. and Obſer. vol. i. p. 56.

Doctor wanted to extract inflammable air from metals by means of heat only, he directed the focus of a lens upon them, whilſt they were under the exhauſted receiver of the air-pump, or were confined by quickſilver.

From pure filings of iron, and of ſteel carefully ſorted with a magnet, and confined by quickſilver in an inverted glaſs jar, Dr. PRIESTLEY, by means of the focus of a lens, obtained ſome permanently elaſtic fluid, which, as he obſerves, was weakly inflammable †.—" I found" (*ſays he*, in vol. iii. of Exper. and Obſer. p. 166) " at this time, that
" eleven grains of *ſteel-filings*, from watch-ſprings, yielded
" $\frac{1}{21}$ more inflammable air, than the ſame weight of iron-
" filings; which agrees with the hypotheſis, that ſteel con-
" tains more phlogiſton than iron."

By directing the focus of the lens upon filings of zinc, or upon braſs-duſt in vacuo, the Doctor obtained inflammable air that was ſtrongly inflammable. But from tin he obtained an elaſtic fluid that was weakly inflammable. With other metallic ſubſtances, or with the calx of any metal whatever, the Doctor had no ſucceſs.

From a mixture of iron-filings and chalk, the Doctor obtained, by means of the lens, a plentiful mixture of fixed and inflammable air, as might be naturally expected ‡.

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† In ſorting the ſteel-filings for this experiment, the Doctor obſerves, that care muſt be taken not to let any other ſubſtance be mixed with them, " ſince
" the leaſt bit of wood, or any vegetable or animal matter, hardly diſcernible by
" the eye, will yield more inflammable air than a conſiderable quantity of iron-
" filings."

‡ Exper. and Obſer. vol. ii. ſect. 6.

The elaſtic fluid expelled from charcoal by heat only, is fixed air; but the reſiduum of it, Dr. PRIESTLEY found to be inflammable *.—Mr. FONTANA had a very elegant way to extract inflammable air from red-hot charcoal. With a pair of tongs he took a piece of charcoal, when thoroughly ignited, and plunging it in water, brought it inſtantly under a large-mouthed receiver, which was filled with and inverted in the water, in order to collect the bubbles of inflammable air that proceeded from the charcoal in the act of cooling. After the ſame manner he treated ſeveral pieces of charcoal, or the ſame piece ſeveral ſucceſſive times, until he got a quantity of inflammable air ſufficient for his purpoſe.

By means of heat in a gun-barrel, Dr. PRIESTLEY obtained from pipe clay, firſt inflammable and then fixed air *.—But a quantity of inflammable air is obtained together with fixed air in various caſes, as we have already remarked.

Pit-coal, by diſtillation, yields inflammable air, which, when fired in a wide-mouthed phial, burns with a bright lambent flame, without exploſion †.

By expoſing to heat, in a gun-barrel, a mixture of calx of zinc and charcoal, or Pruſſian blue, Mr. de LASSONE obtained an inflammable air, which burned without exploſion.

Dr. PRIESTLEY found, that when iron-filings and brimſtone, moiſtened with water, were confined by quickſilver, and ſuffered to ferment in a warm place, ſome inflammable

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* Exper. and Obſer. vol. ii. p. 215.

† Ibid. vol. iii. preface.

air was generated. Filings of zinc and brimſtone produced the ſame effect *.

By taking electric ſparks in any kind of oil, ſpirit of wine, ether, or ſpirit of ſal ammoniac, Dr. Priestley obtained inflammable air. The oil, or other liquor, was confined in a glaſs tube by quickſilver, and a wire was cemented in the upper part of the tube, through which the ſparks being ſent, went to the quickſilver through the oil; but after that a few ſparks had been taken, a quantity of inflammable air was generated, &c.—Leſt the production of inflammable air ſhould be attributed to the cement which faſtened the wire, the Dr. repeated the experiment with ether in a glaſs ſyphon; but the inflammable air was generated as before. This elaſtic fluid does not loſe its inflammability by being paſſed ſeveral times from one veſſel into another through water †.

Alkaline air, by taking electric exploſions in it, is changed into inflammable air; but we ſhall take notice of it again in the chapter on alkaline air.

By means of acids, inflammable air is obtained in greater abundance, and more readily ‡. Iron, zinc, or tin, yield

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* Exper. and Obſer. vol. iii. p. 258.

† Ibid. vol. i. part. 2. ſect. 5.

‡ "It is ſomething remarkable, that all the acids that produce any air by "the ſolution of metals, give inflammable air, except ſpirit of nitre only, "which forms a different kind of union with the inflammable principle, "making *nitrous air*, more or leſs modified; in one of which modifications, "however, it is in a peculiar manner inflammable."—Priestley's Exper. and Obſer. vol. iii. p. 255.

plenty of inflammable air when acted on by diluted vitriolic or marine acids.

If iron is put into ſtrong vitriolic acid, the quantity of elaſtic fluid that is produced is very little, except heat be applied to the phial, for then the production of elaſtic fluid is more copious; but this elaſtic fluid is vitriolic acid air, mixed with a ſmall portion of inflammable air, the proportional quantity of it being leſs when the acid is more concentrated.

Zinc, treated after the ſame manner, produces the like effects, except that it gives more elaſtic fluid, without the application of heat, than iron does; and the greateſt part of the produced elaſtic fluid is inflammable.

In order to obtain the greateſt quantity of inflammable air from iron or zinc, the vitriolic acid muſt be diluted with much water, as about one part of ſtrong oil of vitriol to five or ſix parts of water. Dr. PRIESTLEY found, that eleven grains of iron yielded 8 $\frac{1}{4}$ ounce meaſures of inflammable air *. According to Mr. CAVENDISH, one ounce of zinc, diſſolved either in the vitriolic or marine acid, yields a quantity of inflammable air equal to the bulk of 356 ounces of water; one ounce of iron, diſſolved by means of vitriolic acid, yields a quantity of inflammable air equal to the bulk of 412 ounces of water; and one ounce of tin yields half as much inflammable air as iron does.

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* Exper. and Obſer. vol. iii. p. 165.

The ſolutions of iron, tin, copper, lead, and zinc, in the marine acid, produce marine acid air, and inflammable air, but in various quantities. The proportion of the former to the latter is as one to eight in iron, as one to ſix in tin, as three to one in copper and lead, and as one to ten in zinc *. Regulus of antimony, diſſolved in marine acid, with the application of heat, yield a ſmall quantity of elaſtic fluid, which is weakly inflammable †.

Dr. PRIESTLEY obtained inflammable air, not only by diſſolving various ſubſtances in marine acid, but alſo by expoſing divers bodies to marine acid air, which is probably the pureſt part of the marine acid. Having admitted iron-filings to this acid air, they were diſſolved by it pretty faſt; half of the elaſtic fluid diſappeared, and the reſt was rendered unabſorbable by water, and inflammable. The ſame effect was produced by almoſt every ſubſtance which contains phlogiſton, as by ſpirit of wine, oil of olives, ſpirit of turpentine, charcoal, phoſphorus, bees-wax, ſulphur, dry cork-wood, pieces of oak, ivory, pieces of roaſted beef, and even ſome pieces of a whitiſh kind of flint.

A greater or ſmaller portion of the acid air was abſorbed, and the reſt ſometimes was all inflammable, and often was partly acid air, which was ſoon abſorbed on the admiſſion of water, and partly inflammable ‡. In ſhort, it ſeems as if this

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* Exper. and Obſer. vol. i. p. 145.

† Ibid. vol. iii. p. 255.

‡ Ibid. vol. i. part 1. ſect. 29. and part 2. ſect. 4.

this acid air, having a great affinity with phlogiſton, ſeparates it from all thoſe ſubſtances which contain it even in ſmall quantity, and from that combination becomes inflammable.

By means of nitrous acid, inflammable air may be obtained from various ſubſtances containing phlogiſton ; but it is always mixed with nitrous air, and ſometimes alſo with fixed, and common or phlogiſticated air, as we have already mentioned in the preceding chapter. If two parts of ſpirit of wine, mixed with one part of nitrous acid, are put into a phial with a ground ſtopple and tube, and the flame of a candle be applied to it, ſo as to heat it gradually, the inflammable air will be produced very readily ; the inflammability of which is, however, not very permanent ; for by a little waſhing in water it may be annihilated. In the ſolution of moſt ſubſtances in nitrous acid, it generally happens, that the elaſtic fluid, which is obtained towards the latter end of the proceſs, poſſeſſes the property of being inflammable : Thus iron, diſſolved in nitrous acid, yields nitrous air ; but when the nitrous air ceaſes to be produced, if the heat of a candle be applied to the ſolution, more elaſtic fluid will be produced, which is inflammable *. " The nitrous " acid," *ſays* Dr. INGENHOUSZ, " when mixed with iron- " filings in a very diluted ſtate, gives, by the aſſiſtance of " a moderate degree of heat, a mixture of different airs,

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* See Exper. and Obſer. vol. iii. p. 133.

" partly fixed, partly common air, and partly phlo-
" giſticated air (which experiment I ſaw at Abbé Fontana's) †."

Conſidering the various productions of different permanently elaſtic fluids, and the remarkable properties of the nitrous acid, it is no wonder that, by the action of this acid upon the very ſame ſubſtance, divers elaſtic fluids ſhould be produced in one and the ſame proceſs; ſince its action, as an acid, may force out of the ſubſtance upon which it acts, the elaſtic fluid contained by that ſubſtance; its combining with the phlogiſton, or other component of that ſubſtance, may form another ſort of permanently elaſtic fluid; and laſtly, by being itſelf decompoſed, may produce reſpirable or phlogiſticated air.

Dr. Priestley has obtained inflammable air by diſſolving zinc and iron in radical vinegar *: and he has alſo obtained it by means of phoſphoric acid. " This acid," *ſays he*, " however, reſembled that of vitriol and radical vinegar in " this, that it readily diſſolved iron, eſpecially with the aid " of a little heat, and with it yielded a ſtrong inflammable " air. But there is ſomething more remarkable in the pro-" duce of inflammable air from it by means of minium.

" In order to try whether this acid had any of the pro-" perties of the nitrous, I mixed it with ſome minium out

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† Exper. upon Vegetables, p. 117.

* Exper. and Obſer. vol. iii. p. 256.

" of which all the air had been expelled by heat. This ſubſtance, in this ſtate, I had found, when mixed with nitrous acid, yields dephlogiſticated air; but no air at all with the vitriolic or the marine acid. The phoſphoric acid mixed with this minium with little or no ſenſible heat, but the mixture expoſed to the flame of a candle yielded air very plentifully, and it was very turbid. I received it in lime-water, but it did not precipitate the lime, except in the ſmalleſt degree. The air I got in this method was not affected by nitrous air, nor did it affect common air, but was ſtrongly inflammable, burning with a bright white flame; and the ſmell of the air was the ſame with that of the ſtrong ſmell of phoſphorus. The yellow minium became of a darkiſh grey colour, or nearly black, by this proceſs *."

In regard to the effects produced by a mixture of acids, Dr. PRIESTLEY makes the following general remark:—" It is ſomething remarkable, that when metals are diſſolved in a mixture of ſpirit of nitre and any other acid, they act in a manner independently of each other; and that the nitrous acid, acting more ſuddenly than the others, produces its greateſt effect at the firſt, as the quality of the air diſcovers; the firſt produce in theſe caſes being always chiefly, and ſometimes almoſt wholly, nitrous. Afterwards, there is an equal mixture of both, and the laſt produce is inflam-

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* Exper. and Obſer. vol. iv. p. 136.

“ mable air. This will alſo be ſeen to be the caſe when “ theſe acids are impregnated with the nitrous vapour, and “ the metals afterwards diſſolved in them.

“ Uſing equal parts of oil of vitriol and ſpirit of nitre, “ diluted with water, in the ſolution of *iron*, the firſt pro- “ duce, and the greateſt part of the bulk of the air, was “ ſtrong nitrous air, and the laſt was inflammable. I ob- “ ſerved alſo, that all the nitrous air came very rapidly, as is “ uſual in the ſolution of iron in ſpirit of nitre; but that “ the moment the effect of the ſpirit of nitre was over, the “ air came equally and moderately; and from this time the “ whole produce was inflammable air *.”

Inflammable air has been obtained by means not only of acids, but alſo of alkalies. “ Mr. DE LASSONE has obtained “ inflammable gaſes by diſſolving *zinc* and *iron* in *alkalies.* “ He diſcovered that liquid *volatile alkali* is capable of diſ- “ ſolving filings of zinc; and that, during the ſolution “ (which requires very little heat) an inflammable gas, capa- “ ble of fulminating, when mixed with air, is expelled from “ the mixture, and may be collected by means of a proper “ apparatus.

“ He has alſo obtained a ſimilar gas from the ſolution of “ filings of zinc by *cauſtic fixed mineral alkali*, which was “ applied to the zinc in a liquid ſtate, and was aſſiſted by a “ boiling heat.

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* Exper. and Obſer. vol. iii. p. 171.

"Filings of *iron*, although leſs ſoluble than thoſe of zinc, "by theſe alkalies, did nevertheleſs yield a gas no leſs in-"flammable and detonating than the preceding. Mr. De "Lassone could not diſſolve either of theſe metals by means "of a mild fixed alkali. He obſerved, however, during the "boiling of this alkali in a liquid ſtate, with filings of theſe "metals, that an elaſtic fluid was produced, which was "found (he ſays) to be common air *."

Dr. Priestley has obtained inflammable air by diſſolving iron-filings in a ſolution of galls; "and very probably," *ſays he*, "the ſame would be produced by means of any other aſ-"tringent ſubſtance. Indeed moſt things, that really *decom-"poſe* the metal, and do not unite with the *whole maſs* of it, "will, I imagine, ſet looſe the phlogiſton it contains, in the "form of inflammable air."

The Dr. having mixed three ounces of pounded galls with water, and ſome iron-filings, covered them with a large jar full of water, and found, that in about one week's time they had produced ſix ounce meaſures of inflammable air, exactly like that produced from iron by means of acids †.

Inflammable air, mixed with fixed air, is alſo obtained from tartar, or cream of tartar.

There is an obſervation to be made upon the production of inflammable air in general, which is, that whether it be produced by the action of heat only, or by means of acids, or by fermentation, its ſtrength, or its inflammability, is always ſtronger when the application of heat, or other proceſs, is *haſtily* performed, and contrariwiſe.

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* Treatiſe on Gaſes, London, 1779, chap. iv.

† Exper. and Obſer. vol. iv. ſect. 34.

The ſpecific gravity of inflammable air, according to Mr. CAVENDISH, is to the ſpecific gravity of common air, as 1 to 12 nearly, when common air is 800 times lighter than water. According to Mr. FONTANA, when the barometer is at a mean height, and the thermometer about temperate, a cubic inch of inflammable air weighs 0,035 grs. and its ſpecific gravity is to that of common air as 1 to 15 nearly. This weight, however, is ſubject to ſome variation, ariſing from the various origin of the gas, and even in ſome meaſure from the ſuddenneſs of the proceſs for making it; the ſtrongeſt inflammable air being generally the lighteſt.

Inflammable air has a very penetrating and diſagreeable ſmell, which, like its inflammability, is ſtronger when it has been made by a quick proceſs; ſo that it will then ſmell even through water.—"This ſmell," *ſays* Dr. PRIESTLEY, "is of three different kinds, according as the air is extracted "from mineral, vegetable, or animal ſubſtances. The laſt "is exceedingly fetid, and it makes no difference, whether "it be extracted from a bone, or even an old and dry tooth, "from ſoft muſcular fleſh, or any other part of the animal. "The burning of any ſubſtance occaſions the ſame ſmell; "for the groſs fume which ariſes from them, before they "flame, is the inflammable air they contain, which is ex- "pelled by heat, and then readily ignited. The ſmell of

" inflammable air is the very ſame, as far as I am able to " perceive, from whatever ſubſtance of the ſame kingdom it " be extracted. Thus it makes no difference whether it be " got from iron, zinc, or tin; from any kind of wood; or, as " was obſerved before, from any part of an animal *."

The property which gives the name to this ſort of elaſtic fluid, affords a moſt admirable phenomenon in philoſophy. To obſerve that an inviſible ſubſtance does actually take fire, and burns with a ſenſible and active flame, is very ſtriking even to the experienced philoſopher. Like other combuſtibles, inflammable air cannot burn except it is in contact with good reſpirable air †. Thus, if a phial full of inflammable air is opened, and the flame of a candle is inſtantly applied to its mouth, the inflammable air will make a ſlight exploſion, becauſe part of it is already mixed with the common air; but afterwards, the candle being removed, it will continue to burn quietly in the neck of the phial, becauſe in that place only it comes into contact with the common air. Its flame is weaker than that of ſpirit of wine.—A two-ounce phial, the mouth of which is about a quarter of an inch in diameter, filled with the ſtrongeſt inflammable air extracted from metals, may continue to burn for about three minutes.

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* Exper. and Obſer. vol. i. p. 57.

† When inflammable air is in contact with reſpirable air, it may be eaſily fired, not only by the flame of a candle, but even by a ſmall (though not every) electric ſpark. Mr. VOLTA has fired it by means of a well-lighted coal without flame,

minutes *. The phenomena obſervable during this quiet combuſtion of inflammable air, are the following:—Whilſt the gas is burning in the neck of the phial, a ſmoke or ſteam is ſeparated from it, and appears to deſcend within the phial; which ſhews that ſome water is ſeparated from the inflammable air in the act of burning. The appearance of the flame is different according to ſeveral cauſes. The inflammable air extracted from metals burns with a whitiſh flame, inclining to green; but between the body of this flame ſome ſparks, ſimilar to thoſe occaſioned by a flint and ſteel, are obſervable on account of their vivid red light; and they dart in every direction, but within the limits of the flame. It was obſerved by Mr. FONTANA, that theſe ſparks were obſervable only in the flame of the inflammable air extracted from metals, and that the inflammable air extracted from animal or vegetable ſubſtances exhibited either none at all or very few of them. " The inflammable air," *ſays he*, " of " metals itſelf, if left in contact with water for a long time, " or ſhook in it till it becomes leſs inflammable, will in great

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flame, by a red-hot iron, and even by a flint and ſteel. But if not mixed with a ſufficient quantity of reſpirable air, the inflammable air is ſo far from being capable of aſſiſting combuſtion, or of being inflamed, that, as Dr. PRIESTLEY ſays in his 4th vol. of Exper. and Obſer. p. 449, it will extinguiſh a red-hot coal. The electric ſparks have no effect upon it, and even gunpowder may be fired in it without any danger, and leaving it as inflammable as it was before.

* If the air be gently blown on one ſide of the aperture of the phial, whilſt the gas is burning in it, ſome of the inflammable air being driven out of it, will let the flame be produced a little way out of the neck of the phial. Sometimes it will appear to fall along the ſides of it.

“ meaſure loſe its ſparkling property, and at laſt loſes it entirely, when it is become in a ſtate of being hardly inflammable. I have obſerved, that the inflammable air is the more difficult to be decompoſed, by being ſhaken in water, as the number of the ſparks it ſhews when burning is greater; and, according to this number of ſparks, the inflammable air makes ſtronger or weaker exploſions when mixed with the dephlogiſticated air *.”

The flame of the inflammable air extracted from vegetable or animal ſubſtances, is generally weaker than that of the inflammable air of metals, which is more active †. When the inflammable air is mixed with a little nitrous air, and is ſet on fire, it burns with a green flame; hence the inflammable air that is obtained by means of ſpirit of nitre generally burns with a green flame, becauſe in that caſe ſome nitrous air is generated along with it. But inflammable air,

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[*] Phil. Tranſ. vol. lxix. p. 359.

[†] In Rozier’s Journal for October 1777, is related the following ingenious experiment of M. Chaussier:—He filled a bladder with inflammable air, which, when the bladder was preſſed, eſcaped from it through a tube faſtened to its neck, and having a copper-ball, perforated with one or more holes, at its extremity. When he directed an electric ſpark to one of the holes of the copper-ball, the inflammable air was kindled, and continued to burn in a ſtream as long as the bladder was preſſed, &c. When, inſtead of a copper-ball, the tube terminated in a perforated point, the inflammable air which came out of it could not be fired by means of electric ſparks, which in the ordinary way cannot be taken upon a pointed termination.—By means of the above-mentioned ſtream of flame proceeding out of the hole of the ball, Mr. Chaussier ſays to have revived metallic calxes without addition; and that metals are melted eaſier by this heat than by a common fire.

when mixed with fixed air, burns with a blue flame. When the inflammable air is mixed with reſpirable air, it explodes on the approach of flame with a report, the ſtrength of which is different according to the purity of the reſpirable air, and to the proportion of the quantities of the two elaſtic fluids in the mixture.

According to Dr. PRIESTLEY, inflammable air requires to be mixed with about two thirds of common air, in order to make the greateſt exploſion. But with one third or one quarter of very pure dephlogiſticated air, inſtead of the common air, the exploſion is much more violent and noiſy.

Mr. CAVENDISH, in order to examine the effects ariſing from the firing of inflammable air, when mixed with different proportions of common air, made ſeveral experiments, the reſult of which I ſhall, for ſhortneſs ſake, exhibit in the following table.

Parts of inflammable and of common air in the mixture.		Effects.
1	9.	Was fired with difficulty, and made very little noiſe.
2	8.	Fired eaſily.—The report moderately loud.
3	7.	Loud exploſion.
4	6.	Exploſion little louder than the former.
5	5.	Exploded like the laſt.
6	4.	An exploſion not loud.
7	3.	Gentle exploſion.
8	2.	Burned without noiſe.

In the firſt of theſe experiments, the flame ſpread gradually through the bottle; in the three next, no light was perceived; in the fifth, a light was ſeen; and in the others, the inflammable air continued to burn in the neck of the phial for ſome time after the exploſion; becauſe, as Mr. Cavendish juſtly obſerves, when the mixture contains more common than inflammable air, the common air is not ſufficient to aſſiſt the combuſtion of the whole quantity of inflammable air, ſo that the remainder of it burns on account of the common air, which, after the exploſion, immediately ruſhes into the bottle.

A mixture of reſpirable and inflammable air may, by means of an electric ſpark, be fired in cloſe veſſels; in which caſe it exerts a great force, though not to be compared to the force of gunpowder *; and it is upon this principle that the inflammable air-piſtols are conſtructed.

If a mixture of one part inflammable and two parts reſpirable air, is fired in a cloſe veſſel, and be not ſuffered to eſcape from it, the elaſtic fluid afterwards remaining will be found to be phlogiſticated air, which ſeems to contain no fixed air. The bulk of this remaining elaſtic fluid is much leſs than the original quantity. That the combuſtion of inflammable air, like other combuſtibles, phlogiſticates reſpirable air, and conſequently that a certain quantity of reſpirable air can aſſiſt the combuſtion of a limited proportion

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* A quarter of an ounce of gunpowder, or even much leſs, in a proper piſtol, drives a bullet with greater violence than ten cubic inches of a mixture of inflammable and dephlogiſticated air in the beſt proportion.

of inflammable air, is elegantly ſhewn by an experiment of Mr. WARLTIRE *.

Inflammable air, mixed with the vapour of nitrous acid, explodes in the ſame manner as when mixed with common air. If a receiver filled with and inverted in a baſin of nitrous acid, be filled with inflammable air, the bulk of the elaſtic fluid will be increaſed; and if afterwards, removing the receiver from the baſin, a candle be applied to its mouth, the inflammable air will explode as if common air had been mixed with it; the vapours of the nitrous acid ſupplying the place of common air. This mixture of inflammable air

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* "I fit," *ſays he*, "a glaſs tube into a tapering cork, and that to a round-"bottomed phial, in ſuch a manner, that a bend in the tube, when hung over "the ſide of a tub, be almoſt two inches under the water, but that the end may "riſe four inches higher than the bend. The phial being charged with the "proper materials for producing inflammable air briſkly, it muſt be lighted "as it diſcharges from the end of the tube, and will continue a flame as long "as any inflammable air riſes, provided care is taken to prevent any moiſture "aſcending along with the air. The phial and its tube being placed "upon the edge of the tub, a receiver, ſuch as for an air-pump, is to be brought "over the burning air, and its edge ſunk in the water upon the bend of the "tube. The inflammable air continues to burn as long as there is common "air in the receiver capable of ſupporting the flame. The appearances in this "experiment are very remarkable. About as much inflammable air vaniſhes "as is equal to the bulk of the common air; the burning is attended with "much light and heat; the common air is contracted full a fifth part of its "original dimenſions; immediately after the flame is extinguiſhed, there ap-"pears, through almoſt the whole of the receiver, a fine powdery ſubſtance like "a whitiſh cloud; and the air in the glaſs is left perfectly noxious. The bent "tube ſhould be ſlipped from under the receiver the inſtant the flame goes out, "to prevent the inflammable air mixing with the other air in the receiver."— Appendix to Dr. PRIESTLEY's Exper. and Obſer. vol. iii.

and nitrous acid, bears a very great reſemblance to gunpowder, as they both contain an inflammable principle, and alſo the nitrous acid, which, when decompoſed, produces reſpirable air capable to aſſiſt the combuſtion of the inflammable ſubſtance. But the property of exploding, which inflammable air acquires from its union with the vapour of nitrous acid, is not laſting; ſo that if the inflammable air thus mixed be paſſed from one veſſel into another through water, the vapours of the acid are abſorbed by the water, and the inflammable air remains in the ſtate it was before *; which ſhews, that the vapour of the acid does not properly combine with the inflammable air. Dr. PRIESTLEY, who firſt diſcovered this property of inflammable air, deduced the following remarks from his numerous experiments, *viz.* "That ſpirit of " nitre takes phlogiſton from inflammable air, becoming of " a deeper colour by this communication with it; that " when the ſpirit of nitre is weak, and phlogiſticated, (as " when it is blue, or green) the inflammable air agitated in " it reſembles a mixture of nitrous and inflammable air; and " that when the ſpirit of nitre is ſtrong, and very pure, in" flammable air agitated in it explodes in the ſame manner " as it does in conjunction with dephlogiſticated air †." In the ſame ſection, he ſubjoins, " that if the inflammable " air continues long in the vapour of ſpirit of nitre, and be " fired in it, without ever being removed from it, it returns

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* Even by ſtanding ſome time the acid vapour is depoſited.

† Exper. and Obſer. vol. iii. p. 260.

" to its former ſtate." Inflammable air contracts no union with fixed air within a few weeks time; however, after being kept together a very long time, they ſeem to affect each other; but this alteration has not hitherto been ſufficiently examined.

The other permanently elaſtic fluids, which are inſtantly abſorbed by water, neither ſeem to enter into any combination with or to alter inflammable air; ſince, if to the mixture of either of them with inflammable air, water be admitted, the former is abſorbed by the water, and the latter remains in its natural ſtate.

Inflammable air is either not at all, or in very ſmall quantity, abſorbed by water, when it is merely ſtanding in it for a few days *. It is only to be obſerved, that the ſurface of the water over which the inflammable air ſtands, is covered with a thin film, which, when the inflammable air has been extracted from iron, is reddiſh, like ochre; but is white, when the inflammable air has been extracted from zinc †.

By long ſtanding in water, Dr. PRIESTLEY has obſerved, that the inflammable air is diminiſhed conſiderably, loſes all its inflammability, and extinguiſhes flame; in ſhort, it becomes

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* " Indeed," *ſays* Dr. PRIESTLEY, " when it is extracted from vegetable or " animal ſubſtances, a part of it will be imbibed by the water in which it ſtands; " but it may be preſumed, that in this caſe, there was a mixture of fixed air ex- " tracted from the ſubſtance along with it."—Exp. and Obſ. vol. i. p. 59.

† Sometimes this film exhibits the various priſmatic colours.

comes like phlogiſticated air. But this effect is not conſtant, ſome hitherto unobſerved circumſtance ſeeming to interfere.

Mr. FONTANA, and alſo Mr. SENNABIER, obſerved, that if inflammable air and water were agitated together in a veſſel cloſe ſtopped, the latter would not abſorb any of the former; but if the veſſel containing the inflammable air was agitated in the water of the tub, then the abſorption took place *. Dr. PRIESTLEY found, that by agitating inflammable air in boiled water for about ten minutes, near one quarter of the gas diſappeared, the remainder being found to have loſt a good deal of its former qualities; for, from being highly noxious to animal life, undiminiſhable by nitrous air, and highly inflammable, it was now become reſpirable, being juſt like common air ſo far phlogiſticated as juſt to extinguiſh flame; was diminiſhable by nitrous air; and was very weakly inflammable. When the inflammable air has been ſo far diminiſhed, it explodes at once on the approach of flame. By a longer agitation in water, the Doctor found that inflammable air loſt quite its inflammability, admitted a candle to burn in it, and, in ſhort, became very nearly as good as common air in every reſpect. The inflammable air becomes ſo good, when, by agitation in water, half, or little more than the half of it has diſappeared.

By a ſtill longer agitation, Dr. PRIESTLEY obſerved, that the inflammable air, after being rendered as good as common air, became again phlogiſticated, as common air is

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* De la FOND, Eſſai ſur differentes eſpeces d'air, p. 259

is wont to do; but the time in which this change happens, the Doctor remarks to be very difficult to be fixed. "I found," *ſays he*, "by repeated trials, that it was difficult "to catch the time in which inflammable air obtained from "metals, in coming to extinguiſh flame, was in the ſtate of "common air; ſo that the tranſition from the one to the "other muſt be very ſhort *."

Dr. PRIESTLEY found, that diſtilled water would imbibe about one fourteenth of its bulk of inflammable air, without having its uſual unpleaſant taſte changed by it †.

In reſpect to the abſorption of elaſtic fluid in general by water, due diſtinction muſt be made between the quantity of elaſtic fluid abſorbed, or retained by the water, and that which diſappears in conſequence of being tranſmitted through the water into the atmoſphere. The former may, by boiling, be again extracted from the water; the latter is abſolutely loſt.

Notwithſtanding the decompoſition of inflammable air when mixed with water, which is ſhewn by what has been ſaid in the preceding pages, Dr. PRIESTLEY, in vol. iii. of his works on air, &c. p. 267, ſays, that “ inflammable air “ does not undergo any change by impregnation with water; “ in which reſpect it agrees with what I have obſerved of “ nitrous air. For having impregnated a quantity of rain-“ water (out of which all its air had been carefully extracted “ by the air-pump) with inflammable air, of which it imbibed “ about one thirteenth of its bulk; about a month after-“ wards, by making it boil in a phial, I expelled from it “ about the ſame quantity of air, and found it to be as “ ſtrongly inflammable as it had ever been. After this “ proceſs, there was a depoſit from the water of a filmy kind “ of matter, probably the earth of the metal that had been “ employed in producing the inflammable air. In both theſe “ reſpects inflammable air reſembles nitrous air.”

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* Exper. and Obſer. vol. i. p. 68.——The following is an obſervation of Dr. PRIESTLEY, which deſerves particular notice:—"It is not a little remarkable, "that thoſe kinds of air which never had been common air, (as inflammable "air, phlogiſticated nitrous air, and nitrous air itſelf) when rendered wholeſome "by agitation in water, ſhould be more diminiſhed by freſh nitrous air, than "common air which had been made noxious, and reſtored by the ſame proceſs; "and yet, from the few trials that I have made, I could not help concluding "that this is the caſe." Exper. and Obſer. vol. i. p. 191.

† Exper. and Obſer. vol. i. p. 69.

The effects ariſing from the agitation of inflammable air in oil of turpentine, as diſcovered by Dr. PRIESTLEY, are very remarkable. “ Having agitated,” *ſays he*, “ a quantity “ of inflammable air in oil of turpentine, I preſently ob-“ ſerved an increaſe of its quantity, and I continued the pro-“ ceſs till it had increaſed one half. Agitation in ſpirit of “ wine produced the ſame effect, but more time was requi-“ ſite for it. Allowing to continue in theſe circumſtances “ all night, I found that one half of the additional quantity “ of air had diſappeared: but by repeating the agitation “ about a quarter of an hour, it was again increaſed as

" much as before. I then examined it, and found that it " was not in the leaſt abſorbed by water, did not affect " lime-water, was but very ſlightly inflammable, and was " diminiſhed by nitrous air almoſt as much as common air; " which is in all reſpects the very ſtate to which agitation in " water would have brought it, except that in water it " would have been conſideraly diminiſhed, inſtead of being " increaſed *."

Inflammable air is alſo abſorbed by various other ſubſtances beſides water.

Dr. Priestley obſerved, that by mixing inflammable air made from iron, with air diminiſhed by iron-filings and brimſtone, a diminution of $\frac{1}{9}$ or $\frac{1}{10}$ took place, but it ſeemed to be afterwards as inflammable as before. He alſo obſerved, that the like effects were produced by a mouſe putrifying in a quantity of inflammable air †.—This gas is alſo abſorbed by charcoal; but this will be mentioned in another part of this work.

I ſhall now briefly relate the effects produced by inflammable air, and animal or vegetable ſubſtances, upon each other; and ſhall, laſtly, conclude this chapter with the account of ſeveral particulars more nearly relating to the nature of this gas.

Plants in general grow pretty well in inflammable air, and

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[*] Exper. and Obſer. vol. iii. p. 266.

[†] Ibid. vol. i. p. 107.

their growth diminiſhes little or nothing the inflammability of the gas. The willow plant abſorbs inflammable air, as has been remarked of common air, and the remainder ſeems to be ſtill as inflammable as before *.

Animal ſubſtances putrefying in inflammable air, generally do not leſſen its inflammability; nor does their putrefaction ſeem to be retarded by this ſort of gas. Animals that are confined in inflammable air, are killed by it nearly as ſuddenly as by fixed air †. When inflammable air, by agitation, in water, is brought into ſuch a ſtate as nearly to reſemble common air, then an animal can live in it. Dr. PRIESTLEY having confined a mouſe in 2 ½ ounce meaſures of the reſiduum of inflammable air, after its having been agitated in water, found, that the mouſe lived in it twenty minutes ‡. Inſects, which can live a conſiderable time in phlogiſticated common air, do alſo live for ſome time in inflammable air; but at laſt they become torpid, and either die, or appear to be dead for a conſiderable time, after which they will recover, if removed into the open air.

The numerous experiments made by Mr. FONTANA, in conſequence of Mr. SHEELE's oppoſition to Dr. PRIESTLEY's theory of reſpiration, aſcertained various particulars relating to the effects of inflammable air upon animals. He found by experiments made upon himſelf, that inflam-

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[*] See PRIESTLEY's works on air, &c. vol. iv. ſect. 30.

[†] See Exper. and Obſer. vol. i. p. 62. and Phil. Tranſ. vol. lxix. p. 338, 339.

[‡] Ibid. p. 67.

mable air, when mixed with ſome common air, could be breathed without danger: That the quantity of air which exiſts in the lungs of a man, even after a uſual, though not forced, expiration, being mixed with a quantity of inflammable air, was ſufficient to render it tolerably apt for reſpiration; the neglect of which circumſtance muſt have probably occaſioned the miſtake of Mr. SHEELE: That the breathing of inflammable air was attended with a peculiar ſenſation of levity to the lungs; but that when a veſſel, containing a large quantity of inflammable air, was applied to the mouth of a perſon, after a forced *expiration*, it was fatal to the higheſt degree. Mr. FONTANA having applied the neck of a bladder, containing about 350 cubic inches of inflammable air, to his mouth, after a very violent expiration, began to breathe it in my preſence. The firſt inſpiration of the inflammable air occaſioned a great oppreſſion upon his lungs; the ſecond, affected him ſo much that he looked very pale; the third and laſt inſpiration of the inflammable air was ſcarce accompliſhed, when, for want of ſtrength, he fell upon his knees, and thus teſtified the noxious quality of the gas.

Experiments ſimilar to thoſe were by the ſame philoſopher repeated upon birds and quadrupeds, but they all tended to confirm the ſame general obſervations. He even ſuſpecting, that poſſibly the inflammable air might act upon ſome other part, beſides the lungs, of thoſe animals which were confined in it with their whole bodies, ſtopped the noſe of ſome animals with ſoft wax, and thus introduced them into receivers containing inflammable air; to the mouths of other animals he applied bladders containing inflammable air, and alſo, by means of glaſs tubes, which reached a good way down the wind-pipe, introduced the inflammable air into their lungs, without expoſing any other part of their bodies to it; but the unfortunate animals conſtantly periſhed after a very few inſpirations.

Mr. SHEELE had advanced, that inflammable air was deprived of its inflammability by reſpiration; but Mr. FONTANA proved that this aſſertion was erroneous; his experiments ſhewing, that the inflammability of this gas was by no means diminiſhed by the reſpiration and death of animals; excepting only when a large animal was confined in a proportionably ſmall quantity of inflammable air, in which caſe the inflammability of it would appear diminiſhed, only becauſe the common air contained in the lungs of the animal would be mixed with it *.

In regard to the intimate nature of this inflammable elaſtic fluid, various have been the opinions of thoſe who have endeavoured to inveſtigate it. Some conſider it to be the pure inflammable principle, *i. e.* phlogiſton; others take it to be a ſulphur, viz. a combination of phlogiſton with an acid; and others again ſuppoſe, that it is a compound of ſeveral ingredients.—That inflammable air contains phlogiſton,

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* Phil. Tranſ. vol. lxix.

giſton, is evident; and that ſome other principle or principles beſides phlogiſton are contained in it, ſeems to be highly probable; but it muſt be confeſſed that we are as yet ignorant of the number, quantity, and reciprocal bonds of thoſe principles.

That the inflammable air is not phlogiſton alone, ſeems to be clearly ſhewn by the exiſtence of the various ſorts of inflammable air, which, although they agree in the common property of being inflammable, yet have ſeveral peculiar properties, which could not be obſerved, if a ſingle homogeneous principle conſtituted inflammable air. It may indeed be ſaid, that thoſe various ſpecies are occaſioned by the mixture of extraneous matters not eſſential to the conſtitution of inflammable air. But this would be a mere ſuppoſition unſupported by experiments; ſince we cannot at preſent, by any means, bring every ſort of inflammable air to a common ſtandard, viz. to have preciſely the ſame properties.

The exiſtence of phlogiſton in inflammable air is ſhewn by other experiments beſides its combuſtion. Meſſieurs MACQUER and DE MONTIGNY obſerved, that inflammable air, obtained from the ſolution of iron or zinc in the vitriolic acid, when applied to ſolutions of mercury, lead, ſilver, and other metals, rendered them blackiſh; which indicates a communication of phlogiſton, and a beginning of reduction [‡].

Dr. PRIESTLEY exhibited a very elegant decompoſition of

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[*] Dict. de Chymie—Gas inflammable.

inflammable air without inflammation. The Doctor had ſound, that a moderate degree of heat produced no change on inflammable air. When the inflammable air was expoſed to heat in a tall jar of flint glaſs, in which it had free liberty to expand, it ſuffered no decompoſition; but when the inflammable air was confined in ſmall tubes of flint glaſs hermetically ſealed, and thoſe tubes were expoſed to a red-heat, the inſide ſurface of the glaſs became black, and the inflammable air contained within them was found much diminiſhed, and, as far as could be obſerved, was changed into phlogiſticated air [*].—The particulars which the Doctor aſcertained in thoſe experiments are the following:—The tubes become black the moment they arrive to a red-heat. The blackneſs is only on the inſide ſurface, and is indelible, ſo that none of it can be ſcraped off without taking off part of the glaſs along with it. The glaſs thus tinged is opaque, but is ſtill a non-conductor of electricity. This effect, as ſuggeſted by Mr. Bewly, ſeems to be owing to the lead in the flint-glaſs, which decompoſes the inflammable air by attracting its phlogiſton; accordingly, the experiment did not ſucceed with *green glaſs* tubes [†]. This experiment ſucceeds as well with the inflammable air extracted from iron, as with that obtained from zinc; and after that the flint-glaſs tube containing it has been expoſed to a red-heat, the elaſtic fluid that is found in it does not render lime-water turbid, is not effected by nitrous air, and is not inflammable. A ſmall quantity of water made blue with the juice of turnſole, being poured into thoſe blackened tubes as ſoon as they were broke open, was not altered in the leaſt; which ſhews, that no acid is diſengaged in this decompoſition of inflammable air. Into one of thoſe blackened tubes the Doctor put ſome minium, then making it red-hot, obſerved, that the blackneſs entirely diſappeared, and the tube remained as tranſparent as before it had been rendered black; the metallic calx having attracted the phlogiſton *.

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[*] Thoſe tubes were about half an inch in diameter, and a few inches long; they were filled with inflammable air by means of quickſilver, and afterwards, being ſtill kept inverted in the quickſilver, were ſealed hermetically by means of the flame of a candle and a blow-pipe; the flame being directed towards their middle, ſo as to part them, &c.

[†] "It appears, therefore," *ſays the Doctor*, "from this experiment, that the "calx of lead, in the form of glaſs, has a ſtronger affinity with phlogiſton than any

Dr. PRIESTLEY found, that inflammable air, by being expoſed to florid blood, was diminiſhed, and though ſtill inflammable, yet was rendered in ſome degree wholeſome by the proceſs, ſo as to be conſiderably diminiſhed by nitrous air †; the blood therefore attracts part of its phlogiſton.

Mr. FONTANA, in his paper on inflammable air, publiſhed in the 69th volume of the Philoſophical Tranſactions, ob-

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" any thing in the compoſition of inflammable air, in a degree of heat capable " of melting glaſs. Or, if there be no proper conſtituent part of inflammable " air beſides phlogiſton, the attraction of the calx is ſo great, as to reduce the " phlogiſton from an elaſtic and uncombined ſtate to a fixed and combined " one."

* Exper. and Obſer. vol. iv. ſect. 34. N° 5.

† Ibid. vol. iii. p. 76.

ſerves, that the inflammable air extracted from metals when burning, ſhews a greater number of the vivid ſparks, mentioned in the preceding pages, than the inflammable air which is extracted from animal or vegetable ſubſtances; and that the inflammable air is the more difficult to be decompoſed, the greater is the number of ſparks it ſhews when burning; "ſo that," *ſays he*, "it ſeems proved by experi-"ments, that the phlogiſtic principle is more fixed, and "in greater quantity, combined with the inflammable air of "metals, than with that of vegetable or animal ſubſtances."

The inflammable air does not only contain phlogiſton, but is incapable of combining with more of that principle; hence it is unfit to aſſiſt reſpiration, combuſtion, &c. The fumes of liver of ſulphur do not diminiſh it. Electric ſparks being taken in inflammable air, appear remarkably red, but do not diminiſh it, nor occaſion any change of colour in the ſolution of archil in water, when the jar, containing the inflammable air into which the ſparks are taken, is inverted in it.

By all the unqueſtionable experiments hitherto made, the exiſtence of an acid in inflammable air, as one of its conſtituent principles, is far from being proved. Sometimes, when the inflammable air is agitated in the tincture of turnſole, it occaſions a very ſlight change of colour, but for the firſt time only; after which, if agitated in another portion of the ſolution of turnſole in water, it produces no ſenſible effect, though it remains ſtill inflammable; which ſhews, that the ſmall portion of acid, which ſometimes exiſts in it, is accidental.

Dr. PRIESTLEY is of opinion, that ſome *earth* enters into the compoſition of inflammable air; but the experiments hitherto made, ſeem to be not ſufficient to demonſtrate it.

I ſhall laſtly mention a curious obſervation, relating to the refractive power of inflammable air, made by Mr. WARLTIRE, and related by himſelf, in the Appendix to the third volume of Dr. PRIESTLEY's Experiments and Obſervations:—"What "I recollect," *ſays he,* "of the attempt to aſcertain the re- "fractive power of different kinds of air, relates to inflam- "mable air only, as the trials with any other did not give "the refraction ſenſibly different from common air; and "having been ever ſince at a diſtance from any of my in- "ſtruments proper for ſuch experiments, I have not had an "opportunity of repeating them. An hollow triangular "priſm, of which the angle we uſed was 72 degrees, was "placed upon a proper ſupport, ſo as to half cover a large "object-glaſs in one of Mr. DOLLOND's perſpectives, and was "ſo turned round as to make the frame of a window, at the "diſtance of 1280 feet, ſeen partly through the priſm and "partly through common air, appear undivided. The "inflammable air was then blown out of the priſm, but no "part of the apparatus was moved; when the frame of the "window ſeen through the priſm, and the common air as "before, ſeemed to ſeparate about four inches."

CHAP. V.

Of Nitrous Air.

NITROUS air, or nitrous gas, is a permanently elaſtic fluid, which is never found naturally in any place upon earth, like fixed or inflammable air, but is entirely artificial.

This elaſtic fluid conſiſts principally of nitrous acid and phlogiſton; ſo that it cannot be produced but from that acid, or, which is the ſame thing, from ſubſtances containing the nitrous acid, and phlogiſton: thus, when the nitrous acid is mixed with metals, or with animal or vegetable ſubſtances which contain phlogiſton, nitrous air is generally produced; but very little or none of this ſort of elaſtic fluid is yielded when the nitrous acid is mixed with metallic calxes, with pure aſhes of vegetable ſubſtances, or, in ſhort, with any ſubſtance which contains little or nothing of phlogiſton. In this caſe, if the mixture is expoſed to a ſufficiently ſtrong degree of heat, the nitrous acid is decompoſed, and dephlogiſticated air is produced; though, as we have already obſerved, in ſome period of the proceſs, a little nitrous air is generally produced, which is owing to the ſmall quantity of phlogiſton which exiſts in moſt if not all metallic calxes, &c.

The variety of elaſtic fluids obtainable when nitrous acid is employed, may be deduced from obſerving, that the nitrous acid itſelf, by being decompoſed, may generate dephlogiſticated air; that, by joining with the phlogiſton of the ſubſtance with which it is mixed, may generate nitrous air; that, by the mixture of thoſe two elaſtic fluids, another elaſtic fluid, namely, phlogiſticated air, may be formed; and that, by its acting as an acid, it may expel one or more other elaſtic fluids from thoſe ſubſtances with which it is mixed.

All metallic ſubſtances, when mixed with the nitrous acid, yield nitrous air. Indeed gold, platina, and regulus of antimony, as they are not diſſoluble in ſimple nitrous acid, muſt be diſſolved in aqua regia, in order to obtain nitrous air from them. Although all metallic ſubſtances, by means of the nitrous acid, may be made to yield nitrous air, yet they do not produce it in equal quantities, with equal facility, and of equal goodneſs. The following are the more remarkable particulars relating to this matter:

Either ſilver, copper, braſs, iron, mercury, biſmuth, or nickel, when mixed with nitrous acid, yield nitrous air in great quantities. Some of them, eſpecially mercury, require the aid of heat in order to produce the elaſtic fluid; the flame of a candle applied to the phial is ſufficient: but others, eſpecially copper and iron, do not want the application of any heat. Gold, platina, and the regulus of antimony, when put in aqua regia, yield nitrous air pretty readily. Among the metals, lead yields nitrous air in the ſmalleſt quantity.

" I poured," *ſays* Dr. PRIESTLEY, " ſmoking ſpirit of nitre " into a phial with a ground ſtopple and tube, containing " 1 ½ ounce meaſures filled with ſmall leaden ſhot, ſo as to " leave no common air at all, either in the phial or in the " tube, and I placed it ſo as to receive the air that might " come from it in water.

" After waiting an hour, in which little or no air was " produced, I applied the flame of a candle, though not very " near to it, and in theſe circumſtances I got about an " ounce meaſure of air: but upon ſome water ruſhing into the " phial, while the candle was withdrawn, air was produced " very plentifully. I collected in all about a quarter of a " pint, and might probably have got much more; but that " the ſalt formed by the ſolution of the lead had ſo nearly " cloſed up the tube, that I thought proper to diſcontinue " the proceſs. The air, both of the firſt and of the laſt " produce, was of the ſame quantity, and ſo far nitrous, " that two meaſures of common air, and one of this, occu- " pied the ſpace of two meaſures only; excepting that the " very firſt and very laſt produce, mixed with common air, " took up a little more room than that which I got in " the middle of the proceſs. When the air was produced " very faſt, it was exceedingly turbid, as if it had been filled " with a white powder *."

Among the ſemi-metals, zinc gives the weakeſt nitrous air, when diſſolved in nitrous acid. The elaſtic fluid produced from it, is moſtly phlogiſticated air. From four pennyweights and 17 grains of zinc, diſſolved in ſpirit of nitre diluted with an equal quantity of water, Dr. PRIESTLEY obtained about twelve ounce meaſures of very weak nitrous air. It occaſioned a very ſlight effervefcence when mixed with common air *.—The Doctor obtained nitrous air even from ſome flowers of zinc. "Having," *ſays he*, "mixed a quan-"tity of blue ſpirit of nitre with flowers of zinc, which "were of a dull colour, and appeared from ſeveral experi-"ments to contain a portion of phlogiſton, it yielded, with "the heat of a candle applied to the phial which contained "it, ſtrong nitrous air; when the common ſpirit of nitre "applied in the ſame manner gave only phlogiſticated air; "the phlogiſton of which came probably from the calx it-"ſelf, though a ſmall portion of it might have been in the "nitrous acid, which I believe is never entirely free from it.

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* Exper. and Obſer. vol. ii. p. 174.

"This experiment alſo ſeems to prove, that an *earth* is "the baſis of nitrous air; for the ſame blue ſpirit of nitre, "which gave nitrous air with theſe flowers of zinc, yielded "no air at all when it was treated in the ſame manner with-"out them †."

The quantity of nitrous air that may be obtained from various metals, is difficult to be aſcertained, on account of the diverſity occaſioned by the ſtrength of the acid, the various nature of the metallic ſubſtance, and the method of performing the experiments. The following is a table of the produces of nitrous air from various metals, extracted from Dr. Priestley's firſt volume of Experiments and Obſervations, p. 128; but which, as the author himſelf intimates, is far from being very accurate.

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* Mr. DE LASSONE ſays, that zinc, when diſſolved in nitrous acid, yields fixed, and not nitrous air.

† Exper. and Obſer. vol. iii. p. 205.

dwt.	grs.		
6	0	of ſilver yielded	17 ½ ounce meaſures.
5	19	of quickſilver	4 ½
1	2 ½	of copper	14 ½
2	0	of braſs	21
0	20	of iron	
1	5	of biſmuth	6
0	12	of nickel	4

In page 225 of the above-mentioned volume, the Doctor mentions, that “ having diſſolved ſilver, copper, and iron in
“ equal quantities of ſpirit of nitre diluted with water, the
“ quantities of nitrous air produced from them were in the
“ following proportion; from iron 8, from copper 6 ¼, from
“ ſilver 6. In about the ſame proportion alſo it was neceſ-
“ ſary to mix water with the ſpirit of nitre in each caſe, in
“ order to make it diſſolve theſe metals with equal rapidity,
“ ſilver requiring the leaſt water, and iron the moſt.”

The various ſtrength of the nitrous acid produces great diverſity in the production of nitrous air. Thus, if copper is diſſolved in ſtrong nitrous acid, it will not produce the leaſt quantity of nitrous air; but when diſſolved in diluted nitrous acid, it produces a great quantity of that elaſtic fluid. The cauſe of this remarkable phenomenon is juſtly explained by Dr. PRIESTLEY, upon two known properties, *viz.* that nitrous acid, when very pure, attracts phlogiſton with eagerneſs; and that, by the contact with the nitrous acid, nitrous air is decompoſed, the acid attracting its phlogiſton. The evident conſequence of thoſe two cauſes is clearly exhibited by the ſolution of mercury; for when ſtrong ſpirit of nitre is poured upon mercury, the ſolution ſoon begins, and is very rapid, yet not a ſingle bubble of elaſtic fluid is produced; but in a ſhort time the acid next to the mercury becomes of an orange-colour, which is an indication of its having acquired phlogiſton, no doubt from the nitrous air, which is decompoſed the moment it is formed, and before its particles could be collected into viſible bubbles. Now, the bubbles of air will begin to be ſeen through the coloured acid, but they diſappear the moment they come into contact with the other tranſparent or pale-coloured acid. But when the whole quantity of acid has acquired the ſtrong orange-colour, then the nitrous air eſcapes from it, &c.; the acid being no longer capable of decompoſing more than a ſmall quantity of it. The mixture of water deprives, as it were, the acid of the power of decompoſing nitrous air. The ſtrong and pale-coloured nitrous acid ſhould be diluted with at leaſt two or three parts of water to one of the acid, for the eaſy production of nitrous air from copper and mercury.

The briſkneſs of the efferveſcence, and the production of nitrous air, are promoted by heat, and alſo by letting the metallic ſubſtance preſent a great quantity of ſurface to the acids.

For the generality of experiments, no other degree of heat is required than that produced by the efferveſcence itſelf, except mercury be uſed, which requires the application of ſome heat. When the metal exhibits a very great ſurface to the acid, as is the caſe when filings are uſed, the efferveſcence and production of nitrous air are often much quicker than can be conveniently managed.

Copper, or braſs, when clipped into flat bits, each about 2 or 3 grains in weight, and about a quarter of a ſquare inch in ſurface, and when diſſolved in nitrous acid properly diluted, yield nitrous air very equably; but if iron be uſed, the pieces of it ſhould be larger and fewer, in ſhort, it ſhould preſent a much leſs ſurface to the diluted acid; otherwiſe the increaſe of heat in the proceſs, and the rapid production of elaſtic fluid, render the operation both difficult and dangerous for the operator.

As the nitrous air is moſtly neceſſary to try the goodneſs of reſpirable air, it is of great conſequence to make it always of one conſtant degree of goodneſs; but this object is anſwered by diſſolving ſubſtances of a very homologous nature in the nitrous acid; therefore it is plain that the metals whoſe nature is more uniform, muſt be preferred for this purpoſe. Accordingly, braſs yields nitrous air of a more uniform nature than iron ; copper is ſuperior to braſs; but pure mercury is ſtill ſuperior to copper, and indeed this is the metal which, conſidering its nature, uniformity of ſubſtance, and eaſy ſolution, is upon the whole the moſt uſeful for this purpoſe.

As to the production of nitrous air from the ſolution of vegetable and animal ſubſtances in nitrous acid, we have already taken ſome notice of it in the preceding chapters ; and in this place I ſhall only mention thoſe obſervations which are of a more general nature, omitting the various fluctuating phenomena, which may be obſerved in almoſt every particular experiment, and which are at the ſame time of no apparent conſequence.

It has been generally obſerved, that ſolid vegetable ſubſtances, when diſſolved in nitrous acid, yield more nitrous air than the animal ſubſtances, though this nitrous air is not ſo pure as that obtained from metals.

Sometimes it contains ſome fixed air, and a good deal of inflammable air, which is moſtly produced towards the end of the proceſs. On the other hand, the nitrous air extracted from animal ſubſtances generally contains a good deal of phlogiſticated air, and ſometimes ſome fixed air. In order to obtain nitrous air from the ſolution of animal and vegetable ſubſtances in nitrous acid, often ſome degree of heat muſt be applied to the phial. The acid alſo ſometimes muſt be

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very concentrated, and in other caſes it muſt be diluted; but it is hardly worth while or practicable to determine with exactneſs all thoſe particular caſes. The various degree of heat that is applied to divers ſubſtances in thoſe experiments, is alone ſufficient to alter in part the quality of the produced elaſtic fluid.—I ſhall now ſubjoin ſome more remarkable experiments relating to this ſubject, which are extracted from Dr. PRIESTLEY's works on air, &c.

" *Gum-arabic* eaſily diſſolves in the nitrous acid, and as it " diſſolves, a great quantity of air is produced, making a " beautiful appearance; but when the acid is nearly ſatu- " rated, it becomes viſcid, and the veſſel gets full of froth.

" Part of this air was fixed, precipitating lime in lime- " water, and being readily abſorbed by water. The re- " mainder was nitrous, almoſt as ſtrong as any *.

" *Camphor*, with diluted ſpirit of nitre, yielded very ſtrong " nitrous air; but required a conſiderable degree of heat *.

" Having poured about a quarter of an ounce-meaſure of " ſmoking ſpirit of nitre, mixed with an equal quantity of " water, upon ſome *pounded charcoal*, and having applied to " it the flame of a candle, I collected a large jar full of air, " in all 28 ounce-meaſures. When about half of this quan- " tity of air was produced, it was impoſſible to apply any " more heat, but the ſpirit of nitre would come over; which " it did, tinged with a deep black. When all the liquor was

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* Vol. ii. p. 135.

" come over, ſtill one-fourth part of the air was produced " with the application of a ſtrong heat. The air of this " whole produce, which was not taken at different times, " was ſtrongly nitrous. Two meaſures of common air, and " one of this, occupied the ſpace of no more than two " meaſures *.

" Mr. Delaval was ſo obliging as to inform me, that all " *aſtringent vegetables*, as *galls*, the *Peruvian bark*, and *green* " *tea*, diſſolve with peculiar rapidity in the nitrous acid, in a " manner not unlike the ſolution of ſeveral of the metals in " the ſame acid; and that a great quantity of air is gene- " rated in the proceſs. I immediately made the experiment " with galls, and was really ſurprized at the effect. The " ſolution was, indeed, aſtoniſhingly rapid; but the quan- " tity of air produced by it was not, ſeemingly, greater than " would have been yielded by the ſame bulk of any other " vegetable ſubſtance, diſſolved in the ſame acid, with more " heat. The air alſo was of the ſame quality with that " which is yielded by moſt vegetable ſubſtances. In this " caſe, more than half of it was fixed air, making lime-water " turbid, and the reſiduum was ſo far nitrous, that two " meaſures of common air, and one of this, occupied the " ſpace of 2 $\frac{1}{2}$ meaſures †."

Ether, ſpirit of wine, and all the eſſential oils, when mixed with ſpirit of nitre and heated, produce a great quantity

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* Vol. ii. p. 138.

† Vol. iii. p. 170.

tity of elaſtic fluid; but very little of it is nitrous air, the greateſt part of it being fixed and phlogiſticated air. In conducting thoſe experiments, the operator ſhould take great care both to uſe ſmall quantities of the materials, and to apply the heat in the moſt gentle manner; becauſe, when the nitrous acid has once begun to decompoſe the oil, its action becomes very great, and the leaſt extraordinary heat is capable to increaſe that action and its conſequences to a prodigious and dangerous degree.

As for the animal ſubſtances, when diſſolved in nitrous acid, they generally yield very little or nothing of nitrous air. The greateſt part of the elaſtic fluid thus obtained from them is fixed, inflammable, or phlogiſticated air. Feathers, hair, milk, and a few others, will be found to give a pretty conſiderable quantity of nitrous air, in proportion to the fixed air that is produced along with it.—In the preface to the third volume of Experiments and Obſervations, &c. Dr. PRIESTLEY mentions his examination of ox-gall, in the following words:—"Ox-gall dried, diſſolves in the nitrous acid "with as much rapidity as vegetable aſtringent ſubſtances, "and yields great plenty of nitrous air; whereas animal "ſubſtances in general yield only phlogiſticated air, with a "mixture of lambently inflammable air, by the ſame treatment. Now it is remarkable, that the gall is ſecreted from "the *venal blood*, which, according to my theory of the uſe "of the blood in reſpiration, is then loaded with phlogiſton;

"while other ſecretions are made from the *arterial* blood, " which has diſcharged its ſurplus of phlogiſton."

In the ſimple diſtillation of nitrous acid, a conſiderable quantity of nitrous air is produced.—The vapour of nitrous acid being mixed with ſeveral ſubſtances, or firſt imbibed by certain bodies, and then applied to other ſubſtances in that combined ſtate, generates a good deal of nitrous air. But the curious particulars relating to this ſubject will, for clearneſs ſake, be mentioned in the chapter on *nitrous acid air*.

The nitrous air by itſelf is colourleſs, like common air, excepting when it is firſt produced, at which time it is ſometimes ſlightly red or clouded, which appearances are owing to ſome ſuperfluous nitrous acid, or to ſome earthy particles, which it carries along with itſelf. Its ſtrong ſmell reſembles that of ſmoking nitrous acid ; but it muſt be obſerved, that when it reaches our noſtrils, it neceſſarily mixes with the common air, and is conſequently decompoſed ; it may therefore be juſtly ſaid, that the ſmell we perceive is not of the nitrous air, but of the nitrous acid, which is ſet looſe on the decompoſition of that air. The ſame may be ſaid of its taſte ; and, in fact, Mr. FONTANA, who ſays to have taſted nitrous air without its coming into contact with the common air, aſſerts that it has no taſte whatever. He aſcertained this curious fact in the following manner :

Firſt he introduced the nitrous air into a bottle of elaſtic gum in water, juſt as is done with glaſs bottles ; then, whilſt the neck of the elaſtic-gum bottle was kept under the ſurface of the water, he brought his mouth ſhut, and void of common air, near the ſaid bottle; and when his mouth was under the ſurface of the water, he introduced the nitrous air in it, by ſqueezing the elaſtic-gum bottle. This experiment, he ſays, may be eaſily performed alſo out of the water; for which purpoſe, the neck of the elaſtic-gum bottle, after being filled with the nitrous air, muſt be compreſſed, and, thus taken out of the water, is introduced through the lips into the mouth *exhauſted of air*, then, by ſqueezing the bottle, the nitrous air is introduced into the mouth without any mixture of common air; in which caſe, Mr. FONTANA ſays that it has no ſenſible taſte [*]. He juſtly remarks the danger attending this experiment; for if the operator happens to draw his breath whilſt his mouth is filled with nitrous air, he may be nearly ſuffocated by it. But in regard to the performance of this experiment, I cannot underſtand how it is poſſible to exhauſt one's mouth entirely of common air.

The ſpecific gravity of nitrous air, according to Mr. FONTANA, is very little greater than that of common air, being to one another as 157 to 152; and one cubic inch of nitrous air weighing 0,399 grs. when the barometer is at a mean height, and the thermometer about temperate. But Dr. PRIESTLEY finds the nitrous air to be rather ſomething lighter than common air [†]. But it ſeems that Mr. FONTANA'S

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[*] Recherches Phyſiques ſur la nature de l'Air Nitreux. Paris, 1776.

[†] In the firſt volume of Experiments and Obſervations, p. 119, Dr. PRIESTLEY ſays, that "neither nitrous air, nor common air ſaturated with nitrous air, "differ

TANA's method of weighing elaſtic fluids, which has been already deſcribed in this work, ſeems to be the moſt accurate.

Nitrous air extinguiſhes flame, but it is often in a ſtate of aſſiſting the combuſtion of a candle in a very particular manner; and in this ſtate ſometimes it ſtill retains the power of diminiſhing common air, though in a ſmall degree. The nitrous air may be obtained in ſuch a ſtate by direct proceſſes, and may be converted into that ſtate after that it has been extracted in the uſual manner. When zinc is diſſolved in nitrous acid, if the nitrous air be taken at different times of the proceſs, it will be found that towards the middle or rather the latter end, the nitrous air is in the above-mentioned remarkable ſtate; viz. it will not only admit a candle to burn in it, but the flame is enlarged (ſometimes becoming four or five times larger) by the addition of another weaker and blueiſh flame round the original flame of the candle; ſometimes this burning is accompanied with a crackling noiſe, as if the candle was burning in dephlogiſticated air [*].—I have

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" differ in ſpecific gravity from common air. At leaſt, the difference is ſo ſmall, " that I could not be ſure there was any; ſometimes about three pints of it " ſeeming to be about half a grain heavier, and at other times as much lighter " than common air."—In his ſecond vol. p. 94, the Doctor ſays to have found, that a quantity of nitrous air weighed 7 dwts. 16 grs. whilſt an equal quantity of common air weighed 7 dwts. 17 grs.

[*] " It is remarkable," *ſays* Dr. PRIESTLEY, " that when a candle is extin- " guiſhed, as it never fails to be, in nitrous air, the flame ſeems to be a little en- " larged at its edges, by another blueiſh flame added to it, juſt before its extinc- " tion." Exper. and Obſer. vol. i. p. 222.

often obtained this kind of nitrous air in ſome period of the proceſs, when iron has been diſſolved in very diluted nitrous acid; but it is not an experiment in which I can ſucceed at pleaſure. *Tin*, diſſolved in nitrous acid, produces a good quantity of it *. By expoſing nitrous air to iron, it may be changed into that ſpecies of it, which will admit a candle to burn. Dr. PRIESTLEY filled an eight-ounce phial with nails, and then with mercury, then diſplaced the mercury by nitrous air, and thus left the phial inverted in mercury. Two months after, the nitrous air was found to be changed into ſuch a ſtate as to admit a candle to burn in it with its natural flame; and by continuing ſtill longer in contact with the iron nails, it was ſo altered, that a candle burned in it with an enlarged flame. Theſe changes however are very irregular, ſo that they ſeldom produce the like effects with the regularity that one might expect. Dr. PRIESTLEY once found, that by the contact of iron in quickſilver, it was ſo changed as to be fired with an exploſion like a weak inflammable air; whilſt another quantity of nitrous air, which had been treated in the like manner for about the ſame length of time, only admitted a candle to burn in it with an enlarged flame †.

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* Exper. and Obſerv. vol. iii. p. 17.

† "Nitrous air, treated in the manner above-mentioned, is diminiſhed about "one fourth by ſtanding in quickſilver; and water admitted to it will abſorb "about half the remainder; but if water only, and no quickſilver, be uſed "from the beginning, the nitrous air will be diminiſhed much faſter and "farther; ſo that not more than one-fourth, one-ſixth, or one-tenth of the original quantity will remain." See Exper. and Obſer. vol. i. p. 216, 217.

By expoſure to iron-filings and brimſtone, nitrous air is gradually diminiſhed; but when the diminution is towards the laſt ſtage, it will be found to be changed into the ſtate of aſſiſting flame; after which it becomes phlogiſticated air. It is very remarkable, that when the nitrous air has been brought into the ſtate above-mentioned, a very little agitation in water deprives it of the acquired property, and then it extinguiſhes flame, and retains in great meaſure the power of diminiſhing common air.

The moſt ſtriking particular in this tranſmutation of nitrous air is, that whereas by aſſiſting the combuſtion of a candle, &c. one would imagine it to be changed into ſalubrious air, it will be found, upon trial, to be ſtill noxious in the higheſt degree, animals being killed as ſoon as they are brought into it.

Conſidering with attention its various properties, it ſeems probable that nitrous air, when converted into the above-mentioned ſtate, is compoſed of two diſtinct fluids mechanically intermixed with each other, *viz.* one part of it ſeems to be changed by the proceſs into good air, whilſt another part retains its noxious quality of ſtimulating, or in ſome other manner affecting the lungs of animals, ſo as to occaſion their death.—Farther experiments are certainly wanting to elucidate this ſubject.

Nitrous air is highly noxious to animal and vegetable life. Even inſects generally die the moment they are put into this gas. Frogs, ſnails, and other animals which do not breathe very frequently, live for ſome minutes in this kind of elaſtic fluid, but at laſt they alſo die; and in general they do not recover, even if taken out before they are quite dead.

Plants periſh very ſoon in nitrous air, and alſo in common air ſaturated with nitrous air. "Alſo, though, in general, "plants die almoſt immediately in water impregnated with "nitrous air, yet in one caſe of this kind, when the ſuperfluous nitrous air was carefully let out under water, ſo that "no part of it was decompoſed in contact with the water, "the plant grew in it remarkably well *."

Although nitrous air is incapable to aſſiſt vegetation and animal life, yet this noxious quality ſeems to be counterbalanced by its remarkable property of hindering putrefaction, ſo that ſeveral ſubſtances may be preſerved in it incorrupt for a conſiderable time. This property of nitrous air was firſt diſcovered by Dr. PRIESTLEY, it was afterwards exaggerated by others into a moſt uſeful quality; but the value of it was laſtly reduced to its real ſtandard by the Doctor himſelf, who thus expreſſes the reſult of his impartial experiments:—"Nitrous air will, indeed, preſerve fleſh-meat from putrefaction; "but after long keeping in this manner, it becomes very offenſive, both to the noſtrils and the palate, though the "ſmell is not altogether that of putrefaction; and indeed, the "ſubſtance continuing quite firm, it could not be properly "putrid †.

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* PRIESTLEY's Exper. and Obſer. vol. iii. p. 321.

† Ibid. vol. iv. § 6.

" In the firſt publication of my papers, having experienced " the remarkable antiſeptic power of nitrous air, I propoſed " an attempt to preſerve anatomical preparations, &c. by " means of it; but Mr. Hey, who made the trial, found " that, after ſome months, various animal ſubſtances were " ſhrivelled, and did not preſerve their natural forms in this " kind of air *."

Conſidering the antiſeptic power of nitrous air, and alſo its being ſo fatal to inſects, it ſeems not improbable but that by ſome means it might be applied for certain diſeaſes to the human body; perhaps, if introduced by way of clyſters into the inteſtines, it might deſtroy the worms in them, &c.; but hitherto I have not heard, that it has been at all tried for ſuch purpoſes in ſome unqueſtionable caſe. Nitrous air, by mere ſtanding by itſelf, *viz.* not in contact with any thing which may be eaſily altered, ſeems not to be decompoſed nor in any way changed. Dr. Priestley found that a quantity of nitrous air, kept in a corked phial, retained its property of diminiſhing common air, as much as it had done at firſt, for about two years †.

The contact only of water is ſufficient to decompoſe nitrous air in a great meaſure. Not only its power of diminiſhing reſpirable air is gradually weakened, but its bulk alſo is diminiſhed.—The diminution of its activity is perceivable even after that the nitrous air has been one day in contact with water; and it is almoſt intirely loſt after two or three months. In this ſtate its peculiar ſmell is very weak, and an animal that is confined in it does not die quite ſo ſoon as it would have done in new-made nitrous air; in ſhort, it is in the ſtate of phlogiſticated air. It is plain, that the various quantity of nitrous air, and of the ſurface of the water to which it is expoſed, muſt occaſion great diverſity in the production of thoſe effects; but even when all the other circumſtances are alike, ſome difference ſeems to be occaſioned by the particular nature of the water, and of the nitrous air.

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* Exper. and Obſer. vol. i. p. 228.

† Ibid. vol. iii. p. 358.

It might be naturally ſuſpected, that the above-mentioned decompoſition of nitrous air is occaſioned by the common air which exiſts in the water, and with which the nitrous air does probably come into contact; but this ſuſpicion is removed by obſerving, that the decompoſition of nitrous air is occaſioned as well by common water, as by water that has been long boiled, or out of which the air has been exhauſted by means of an air-pump.

By agitation, water may be made to imbibe about one tenth of its bulk of nitrous air, and afterwards the nitrous air may be again extracted from it by boiling. The water to be employed in this experiment ſhould be previouſly deprived of its air. "I carefully pumped," *ſays* Dr. PRIESTLEY, "all "the air out of a quantity of rain-water, letting it ſtand 24 "hours in a very good vacuum, and then impregnated it with "nitrous air; when, immediately expelling all that I could

" of it by the heat of boiling water, I found no part of it " fixed air, but all pure nitrous air, though not more than " one fourth of the quantity that had been imbibed by " it*."

Dr. Priestley has alſo obſerved, that by freezing, water is deprived of all the nitrous air with which it has been impregnated; and he remarks, that water impregnated with nitrous air does not freeze ſo ſoon as a quantity of the ſame water not impregnated with this gas †. When nitrous air is agitated in a large quantity of water for about a quarter of an hour, all the part of it that is miſcible with water is abſorbed by it, and the portion which remains is phlogiſticated air; but if the agitation is continued ſtill longer, this phlogiſticated air is purified ſo far as to be reſpirable, and to be diminiſhable by other nitrous air. Dr. Priestley, who made this remarkable diſcovery, relates one of his experiments in the following words:—" In a pretty long time I " agitated nitrous air in water, ſupplying it from time to time " with more, as the former quantity diminiſhed, till only " one eighteenth of the whole quantity remained; in which " ſtate it was ſo wholeſome, that a mouſe lived in two ounce " meaſures of it more than ten minutes, without ſhewing " any ſign of uneaſineſs; ſo that I concluded it muſt have " been about as good as air in which candles had burned " out.

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* Exper. and Obſer. vol. iii. p. 109.

† Ibid. vol. iii. p. 359.

"After agitating it again in water, I put one part of freſh "nitrous air to five parts of this air, and it was diminiſhed "one ninth part.

"I then agitated it a third time, and putting more nitrous "air to it, it was diminiſhed again in the ſame proportion; "and ſo a fourth time: ſo that, by continually repeating "the proceſs, it would, I doubt not, have been all abſorbed. "Theſe proceſſes were made in lime-water, without forming "any incruſtation on the ſurface of it *."

Freſh-made nitrous air is more eaſily and in greater quantity abſorbed by water, than that which has been kept a long time.

Water, impregnated with nitrous air, acquires very little acidity, ſo that it can be juſt diſcovered by the tincture of turnſole †; but, as Mr. BEWLY obſerved, if common air comes into contact with it, then the nitrous air being decompoſed, the water will become very ſenſibly impregnated with nitrous acid. Mr. BEWLY impregnated ſome water with nitrous air, and then ſaturated it with fixed alkali; laſtly, by evaporating this water, he obtained ſome cryſtals of nitre. Indeed, the decompoſition of a large quantity of

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[*] Exper. and Obſer. vol. i. p. 190.

[†] If a pretty large quantity of nitrous air is admitted into a jar containing a ſolution of turnſole in water, out of which the air has been extracted by boiling or otherwiſe, the ſolution will become evidently red, and, as Mr. FONTANA obſerves, much more ſo than if the ſaid ſolution had not been deprived of its air. —This redneſs of the tincture of turnſole may be rendered ſtill more conſpicuous by a little agitation.

nitrous air, by means of common air in contact with water, may impregnate the water with nitrous acid to ſuch a degree, as to render it ſtrong *aqua fortis.* "I found," *ſays* Dr. PRIESTLEY, "that I could make 4 ½ ounce meaſures of "water receive all the acid that could be ſupplied by 300 "ounce meaſures of nitrous air; and that then the water "was become quite blue. But water, impregnated with the "nitrous acid vapour, either in this manner, or from the ſo-"lution of metals in ſtrong nitrous acid, adheres to it very "ſlightly, and can hardly be prevented from making its eſ-"cape *."

From the above-mentioned obſervations it appears, that the nitrous acid exiſts in nitrous air in a ſtate of combination with the other components of that permanently elaſtic fluid, ſo as not to be perceived in it except when the nitrous air is decompoſed; and that the pureſt water, even when deprived of its air, is capable of decompoſing that elaſtic fluid.

When water impregnated with nitrous air is left expoſed to the atmoſphere, or is froze, ſo that the gas may eſcape from it, a ſediment is obſervable in the veſſel, which generally is of a browniſh colour, though ſometimes it is whitiſh. The colour of this ſediment ſeems not to depend at all upon the kind of metal uſed for the production of the nitrous air, ſince when the very ſame metal has been employed, the ſediment is ſometimes brown and ſometimes whitiſh. This ſediment however ſhews, that an earthy matter enters into the compoſition of nitrous air.

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* Exper. and Obſer. vol. iii. p. 161.

Beſides water, nitrous air is abſorbed by various other fluids, and the phenomena obſervable in ſome caſes of that ſort are very remarkable. Strong and colourleſs oil of vitriol imbibes about as much nitrous air as water can do. It requires about the ſame degree of agitation; and from this impregnation acquires a purple colour *. Marine acid imbibes a very ſmall quantity of nitrous air, and very ſlowly, and by this impregnation it becomes of a light-blue colour *. The nitrous acid abſorbs nitrous air with remarkable quickneſs, and from this impregnation its colour is changed †. Dr. PRIESTLEY deſcribes one of his experiments, relating to this point, in the following manner:—" Having filled a phial, containing exactly the quantity of four penny-weights of water, with a " ſtrong pale yellow ſpirit of nitre, with its mouth quite cloſe " to the top of a pretty large receiver, ſtanding in water, I " carefully drew out almoſt all the common air, and then " filled it with nitrous air; and as this was abſorbed, I kept " putting in more, till, in leſs than two days, it had compleatly abſorbed 130 ounce meaſures.

" Preſently after this proceſs began, the ſurface of the

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* See Exper. and Obſer. vol. iii. p. 129.

† This change of colour is evidently owing to the phlogiſton, which the nitrous acid acquires from the nitrous air.

" acid aſſumed a deep orange-colour, and when 20 or 30 " ounce meaſures of air were abſorbed, it began to be ſenſibly green at the top; and this green kept deſcending " lower and lower, till it reached the bottom of the phial. " Towards the end of the proceſs, the evaporation of the " acid was perceived to be very great; and when I took it " out, the quantity was found to have been diminiſhed exactly one-half; for there remained no more than the quantity " of two penny-weights of water. Alſo it had become, by " means of this proceſs, and the evaporation together, exceedingly weak, and was rather blue than green *."

It is very remarkable, that both nitrous air, and common air phlogiſticated by nitrous air, are meliorated by agitation in nitrous acid; ſo that they ſuffer a ſenſible diminution if afterwards they are mixed with other nitrous air †.

Radical vinegar, and the *concentrated vegetable acid*, abſorb nitrous air much faſter than water; and the latter aſſumes a dark purple, whilſt the former is not altered by this impregnation ‡.

The ſolution of green vitriol in water imbibes nitrous air much eaſier than water, and in a far greater quantity. By this impregnation the ſolution acquires a black colour; but which acquired colour it loſes by expoſure to common air.

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* Exper. and Obſer. vol. iii. p. 123.

† Ibid. p. 128.

‡ Ibid. p. 130.

Its taſte becomes alſo acid, owing no doubt to the nitrous acid acquired from the nitrous air *.

Cauſtic alkalies abſorb very little of nitrous air.

Olive-oil abſorbs a conſiderable quantity of nitrous air, but very ſlowly. By this impregnation the oil is coagulated.

Oil of turpentine abſorbs nitrous air very faſt, and in large quantity. If a little agitation be uſed, the oil of turpentine may be made to imbibe more than ten times its bulk of nitrous air, and that in as eaſy a manner as fixed air is made to mix with water. By this impregnation the oil acquires a yellowiſh or orange-colour, and becomes a little glutinous. That part of the nitrous air which is not abſorbable by the oil of turpentine, remains in the ſtate of phlogiſticated air †.

"Ether," *ſays* Dr. Priestley, "has the ſame power of "abſorbing nitrous air that oil of turpentine poſſeſſes."— That part of it which is not abſorbed, poſſeſſes no nitrous property ‡.

Spirit of wine abſorbs nitrous air very faſt, but is ſoon ſaturated with it, ſo that it cannot imbibe much more than its own bulk of it. By this impregnation the ſpirit does not acquire any colour §. If heat be applied, either to the ſpirit of wine

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* Experiments and Obſer. vol. iv. p. 48 and 52.

† Ibid. vol. iii. p. 112.

‡ Ibid. p. 115.

§ Ibid. p. 119.

or to the oil of turpentine, thus impregnated, no nitrous air will be obtained from them.

The mixture of iron-filings and brimſtone, made into a paſte with water, abſorbs about three fourths of a quantity of nitrous air that is expoſed to it, the proceſs being accompanied with heat.—“ The effect of this proceſs is generally “ perceived in five or ſix hours, about which time the viſible “ effervеſcence of the mixture begins; and in a very ſhort “ time it advances ſo rapidly, that in about an hour almoſt “ the whole effect will have taken place *.”—The reſiduum does not ſmell like nitrous air; it is not abſorbable by water, nor by a freſh mixture of iron-filings and brimſtone; in ſhort, it is phlogiſticated air †.

Liver of ſulphur diminiſhes nitrous air in a very great proportion, by combining with its acid; the reſiduum ſometimes being leſs than the twentieth part of the whole quantity.

When about three fourths of the nitrous air are thus diſappeared, the remainder is in the ſtate of phlogiſticated air ‡.

Mr. Bewly's *pyrophorus*, of which mention has been made above, does alſo decompoſe nitrous air, and leaves the reſiduum in the ſtate of phlogiſticated air §.

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* Exper and Obſer. vol. i. p. 118.

† This decompoſition of nitrous air, by iron-filings and brimſtone, does not impart the leaſt perceivable acidity to the water over which it is made; it is therefore clear, that the nitrous acid muſt be imbibed by the mixture.

‡ The diminution of nitrous air, by brimſtone and iron-filings, or by liver of ſulphur, happens in the very ſame manner in quickſilver as in water. Exper. and Obſer. vol. i. p. 225.

§ Priestley's Exper. and Obſer. vol. iv. p. 64.

The phoſphorus of urine gives no light in nitrous air.

Electric ſparks do alſo decompoſe nitrous air.—"I nearly "filled a phial, containing about ſix ounce meaſures of ni"trous air, confined by quickſilver; and taking the electric "ſpark within it, it was in about an hour diminiſhed about "one half, but after that very little. The quickſilver was "much corroded, and a candle went out in the remainder of "the air.——I repeated the experiment in a tube a quarter "of an inch in diameter, receiving the ſpark upon water "tinged blue with the juice of turnſole; and the diminution "was ſo quick, that the motion of the water up the tube was "conſtantly ſenſible to the eye. The water was deeply and "permanently red *."

Having expoſed a quantity of very florid blood to nitrous air, Dr. Priestley obſerved, that the gas was conſiderably diminiſhed by it, and loſt part of its power of diminiſhing common air. It ſeems evident, that the blood attracts the phlogiſton of the nitrous air †.

The effects produced by a bladder upon nitrous air, as they were aſcertained by Dr. Priestley, are very remarkable. —If a bladder full of nitrous air is kept intirely under water, or quite out of it, the nitrous air is very little altered, perhaps not more than if it had been confined by water in glaſs veſſels; but if the bladder containing the nitrous air be alternately wetted and dried, then the nitrous air is diminiſhed,

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[*] Priestley's Exper. and Obſer. vol. iv. p. 64.

[†] Exper. and Obſer. vol. iii. p. 76.

decompoſed, and, when the diminution is accompliſhed, which will take place after about two or three days, the reſiduum, which is about $\frac{1}{4}$ of the whole, will be found to be phlogiſticated air *. In this decompoſition, both the phlogiſton and the acid of the nitrous air are evidently imparted to the water, ſince this taſtes very acid, and eaſily phlogiſticates common air. "Having put rain-water into a bladder, "and filled it up with nitrous air, I tied it up very cloſe, "and left it to ſwim in a baſon of water, taking care that "the mouth of it was always under the water. After a "week, perceiving that it was ſhrunk up to about one fourth "of its bulk, I opened it, carefully preſſing out the water "into a clean phial; when I found the air within it "thoroughly phlogiſticated, not affecting common air in the "ſmalleſt degree, and the water was exceedingly acid, very "turbid, a little inclined to yellow, and preſently made a "depoſit of the ſame colour †."

From all the above-mentioned phenomena it appears, that nitrous air is decompoſed whenever it meets with any ſubſtance capable of attracting its phlogiſton or its acid. When one of thoſe principles is attracted, the other components of the nitrous air are ſet at liberty. Hitherto it has not been obſerved, that any ſubſtance decompoſes nitrous air by attracting ſome other of its components beſides the acid and

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* The beſt method of performing this experiment is, to leave the bladder, that contains the nitrous air, to ſwim over the ſurface of the water.

† Exper. and Obſer. vol. iii. § 14.

the inflammable principles; though this may perhaps happen in ſome circumſtance or other. It appears alſo, that the elements of nitrous air are pretty eaſily ſeparable from each other; perhaps eaſier than thoſe of any other permanently elaſtic fluid. The phlogiſton, for inſtance, of inflammable air will not be ſeparated from the other components of the inflammable air, nor can it be imparted to common air without a great degree of heat or actual inflammation; but the phlogiſton of nitrous air is eaſily communicated to common air on the very firſt contact, and without the application of any heat.

The general obſervation, *viz.* that nitrous air is decompoſed only when it meets with any ſubſtance that has affinity with any of its two principal ingredients, takes place alſo in the mixture of nitrous air, and other permanently elaſtic fluids.—“ *Nitrous air,*” *ſays* Dr. Priestley, “ admitted to alkaline air, likewiſe occaſioned a whitiſh cloud, “ and part of the air was abſorbed; but it preſently grew “ clear again, leaving only a little dimneſs on the ſides of the “ veſſel. This, however, might be a kind of ſalt, formed “ by the union of the two kinds of air. There was no “ other ſalt formed, that I could perceive. Water being admitted to this mixture of nitrous and alkaline air, preſently “ abſorbed the latter, and left the former poſſeſſed of its “ peculiar properties *.”

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* Exper. and Obſer. vol. i. p. 171.

Nitrous air is alſo diminiſhed by nitrous acid vapour, and the remainder is left in the ſtate of phlogiſticated air; but we ſhall take particular notice of it in the chapter on *nitrous acid air*, or *vapour*.

The mixture of nitrous air with the other elaſtic fluids, that are not reſpirable, does not preſent any remarkable phenomena; but when nitrous air is admitted to common or dephlogiſticated air, or, in ſhort, to any reſpirable air, the effects ariſing from it are very ſtriking.

It has been already ſufficiently remarked, that the mixture of nitrous and reſpirable air occaſions a redneſs, heat, and a diminution of the bulk of both elaſtic fluids, which is in proportion to the goodneſs of the reſpirable air; being greater when the reſpirable air is purer, and contrariwiſe. But in this place we ſhall take notice of ſome other particulars, which are more nearly related to the nature of nitrous air. That, when nitrous air is mixed with reſpirable air, both of them muſt ſuffer a diminution, is evident from the remainder, which in ſome caſes is leſs than the bulk of either of the elaſtic fluids employed; but it is difficult to determine how much of each elaſtic fluid is diminiſhed. Dr. PRIESTLEY remarks, that the diminution is not of equal quantities of the two elaſtic fluids, "but," *ſays he*, "of about one "fifth of the common air, and as much of the nitrous air as "is neceſſary to produce that effect; which, as I have found "by many trials, is about one third as much as the original "quantity of common air. For if one meaſure of nitrous

“ air be put to two meaſures of common air, in a few “ minutes (by which time the effervefcence will be over, and “ the mixture will have recovered its tranſparency) there will “ want about one ninth of the original two meaſures; and “ if both the kinds of air be very pure, the diminution will “ ſtill go on ſlowly, till, in a day or two, there will remain “ only one fifth of the original quantity of common air *.”

The Doctor alſo obſerves, that if a ſmall quantity of common air be admitted to a large quantity of nitrous air, a diminution will take place ; but yet their joint and diminiſhed bulk will be always greater than the original quantity of nitrous air only. “ One ounce meaſure of common air being “ put to near 20 ounce meaſures of nitrous air, made an ad- “ dition to it of about half an ounce meaſure †.”

Mr. LAVOISIER ſays, that 16 parts of common air, and $7\frac{1}{3}$ parts of nitrous air, are requiſite for a complete ſaturation, and that in this caſe the whole quantity of nitrous, and one fourth of the common air diſappear. Mr. FONTANA is alſo of opinion, that the greateſt diminution is ſuffered by the nitrous air ‡; and indeed this opinion ſeems to be true upon various conſiderations. Firſt, if we reflect upon Dr. PRIESTLEY's experiment, mentioned in his fourth volume of Experiments and Obſervations, p. 246, *viz.* when he found that two meaſures of nitrous air, being mixed with one meaſure of dephlogiſticated

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[*] Exper. and Obſer. vol. i. p. 110.

[†] Ibid. p. 112.

[‡] Recherches Phyſiques ſur l'Air Nitreux.

dephlogiſticated air, the ſum of their bulks, after the diminution, was equal to $\frac{3}{100}$ths of a meaſure, we muſt conclude, that the nitrous air ſuffered the greateſt diminution; for, even ſuppoſing that the whole of the dephlogiſticated air had diſappeared, yet two meaſures, leſs $\frac{3}{100}$ths of a meaſure of nitrous air, muſt alſo have diſappeared, which is more than the original quantity of the dephlogiſticated air employed. Secondly, it is known by various other experiments, that when common air is completely phlogiſticated by any other mean, in which the air is not abſorbed, the diminution of common air amounts to about one quarter of the whole quantity, and afterwards the remaining two thirds are completely phlogiſticated, ſo that nitrous air cannot diminiſh it any farther. Therefore it ſeems natural to ſuppoſe, that when common air is completely phlogiſticated by nitrous air, it ſuffers the ſame diminution. Now, if one meaſure of nitrous is mixed with two meaſures of common air, after the diminution, the joint bulk of thoſe two elaſtic fluids will be found to be equal to about 1,95 meaſure; ſo that one meaſure, more five hundredths of a meaſure, of elaſtic fluid are vaniſhed; from which taking away half a meaſure (which is one quarter of the whole) for the diminution of two meaſures of common air, ſtill more than half a meaſure (properly 0,55 of a meaſure) are wanting, which is evidently the diminution ſuffered by the nitrous air, and is greater than the diminution of the common air.

The effects obſervable when nitrous air is mixed with reſpirable air, *viz.* the redneſs, the turbid appearance, the heat, and the diminution of bulk, are altered by ſeveral circumſtances. If the proceſs be performed in quickſilver, the redneſs does not diſappear ſo ſoon as in water. The diminution requires alſo a longer time before it be compleated, and at laſt it is not ſo great as when the proceſs is performed in water. If, after that the two elaſtic fluids have been mixed in quickſilver, ſome water be admitted into the veſſel, the redneſs of the mixed elaſtic fluid will ſoon ſubſide, and its bulk will thereby be diminiſhed a little farther. But the moſt remarkable circumſtance is, that if the water be admitted a ſhort time after the mixing of the two elaſtic fluids, the above-mentioned *farther diminution* will be more conſiderable, than if the water be admitted a longer time after the mixture. After about 8 hours, this diminution of the mixt elaſtic fluid, occaſioned by the admiſſion of water, is juſt perceivable, but no ſenſible diminution will happen if the water be admitted about 12 hours after.—“ It is evident,” *ſays* Dr. PRIESTLEY, “ from theſe experiments, that the di-“ minution is in part owing to the abſorption by the water ; “ but that when the mixture is kept a long time in a ſituation “ in which there is no water to abſorb any part of it, it ac-“ quires a conſtitution by which it is afterwards incapable of “ being abſorbed by water *.”

The redneſs ariſing from the mixture of nitrous and reſpirable air, is certainly owing to the nitrous acid which is ſet at liberty, when the other principal component of nitrous air, *viz.* the phlogiſton, is attracted by and combines with the common air *.—The vapour of the nitrous acid in this caſe is condenſed, and aſſumes the properties which that acid is wont to have, *viz.* it combines with alkalies, it renders acid the water that abſorbs it, (and we have already remarked, that water can abſorb the nitrous vapour of a vaſt quantity of decompoſed nitrous air) it reddens the blue tincture of vegetables, and it even corrodes the quickſilver, when the proceſs is made in this fluid. It is for this reaſon, that the redneſs ariſing from the mixture of reſpirable and nitrous air diſappears ſooner in water than in quickſilver, and ſtill ſooner if the veſſel be agitated in water.

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* Exper. and Obſer. vol. i. p. 113.

Dr. PRIESTLEY has a very fine method of ſhewing the mixture of alkali with the nitrous acid vapour in the abovementioned caſe.—“ In diverſifying,” *ſays he*, “ this experi-
“ ment, I found, that it appeared to very great advantage
“ when I ſuſpended a piece of volatile ſalt in the common
“ air previous to the admiſſion of nitrous air to it, incloſing
“ it in a bit of gauze, muſlin, or a ſmall net of wire. For,
“ preſently after the redneſs of the mixture begins to go off,
“ the white cloud, like ſnow, begins to deſcend from the
“ ſalt, as if a white powder was ſhaken out of the bag that

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* It is evident, that when common air has been thus completely phlogiſticated, any farther addition of nitrous air will not occaſion any diminution or redneſs, becauſe the air is rendered incapable of attracting more phlogiſton, and conſequently of decompoſing more nitrous air.

"contains it. This white cloud preſently fills the whole "veſſel, and the appearance will laſt about five minutes *."

If the nitrous and common air be mixed together by little and little, as muſt be the caſe when a very narrow veſſel is uſed, and without any agitation, the diminution is leſs than it would have been, if the ſame quantities of elaſtic fluid had been mixed in a wide veſſel, where almoſt the whole of one elaſtic fluid could have come into contact with the other. This obſervation ſeems to ſhew, that the beſt method of examining the purity of reſpirable air, by means of the nitrous taſte, would be, to mix the two elaſtic fluids in a large veſſel; but then we meet another objection, which is, that in the large veſſel the diminiſhed bulk of elaſtic fluid cannot be meaſured with exactneſs. It might indeed be afterwards paſſed from the large veſſel into a narrow one, in order to meaſure its quantity; but the mixture of nitrous and common air ſuffers a little diminution by being thus paſſed from one veſſel into another through water; and this diminution is greater or leſs, according as the mixed elaſtic fluid is paſſed through the water ſooner or later after being mixed. It varies alſo according to the different proportion of the two elaſtic fluids; which would occaſion a conſiderable uncertainty.

The mixture of nitrous and common air occaſions alſo a precipitation of lime in lime-water; which ſhews, that ſome

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* Exper. and Obſer. vol. i. p. 210.

fixed air is generated, but the quantity of it is very ſmall; ſo that when ſmall quantities of the two elaſtic fluids are uſed, the whole proceſs muſt be made in lime-water, in order to render the precipitation of the lime manifeſt. The very ſmall quantity of the fixed air thus generated, is far from juſtifying the ſuſpicion that the diminution obſerved in the mixture of nitrous and reſpirable air is entirely, or in great part, owing to the precipitation of fixed air.

All the above-mentioned circumſtances, which alter the diminution occaſioned by mixing nitrous and reſpirable air, confirm and ſhew the reaſons of the remark repeatedly made in the preceding part of this work, in which ſeveral particular methods of examining the purity of reſpirable air by the nitrous taſte were deſcribed; *viz.* that unleſs the experiments be made conſtantly in the ſame uniform manner, no dependance can be put upon their reſults.

It has been mentioned towards the beginning of this chapter, that nitrous air was principally compoſed of nitrous acid and phlogiſton; and the above-related properties evidently demonſtrate the truth of the propoſition; yet ſome doubt might be entertained in regard to the mode of the exiſtence of the nitrous acid, which might be thought unneceſſary to the conſtitution of nitrous air, and as being only mechanically ſuſpended in that elaſtic fluid; but, without any other conſideration, this ſuſpicion is eaſily removed by an experiment of the DUC DE CHAULNES. This great philoſopher introduced the tincture of turnſole into a quantity of nitrous air, by means of an apparatus which prevented the entrance of any common air into the nitrous air, and alſo prevented the tincture from touching the water by which the nitrous air was confined in the glaſs veſſel. The reſult of this experiment was, that the tincture did not become red in the leaſt degree; which ſhews, that the acid of the nitrous air exiſts in a ſtate of combination with the other components of that elaſtic fluid, in which ſtate it cannot ſhew any properties of an acid, no more than the vitriolic acid can ſhew any acid property whilſt it exiſts in a ſtate of combination with the inflammable principle in a piece of ſulphur *. The inſtrument uſed for this curious experiment is delineated in fig. 11. plate III. It conſiſts of two bent wires, A B C and D E F, whoſe form is clearly ſhewn by the figure. The wire A B C holds a ſmall glaſs veſſel I, at its extremity C, into which the tincture is to be put, and has two ſockets G and H, through which the other wire D E F ſlides up and down. To the end F of this other wire, the covering of the veſſel I is faſtened, which, when the wire D E F is puſhed down, ſhuts the mouth of the veſſel I, and uncovers it when the ſaid wire is drawn a little way upwards.

When the tincture, &c. is put into the veſſel I, and the covering F cloſes it, the operator, holding the inſtrument by A D, plunges it into the water of the tub in which the jar

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* We have remarked, in the preceding pages, that the tincture of turnſole is turned red by agitating nitrous air in it; but in that caſe the nitrous air is decompoſed, as it is decompoſed when agitated in the pureſt water.

with the nitrous air is ſtanding, brings the part I C F G under the jar, and, drawing the inſtrument upwards in an erect poſition, elevates the part I C F G above the ſurface of the water within the jar, and the part D A B E out of the ſaid jar; then, holding the wire A ſteady, pulls the wire D upwards, which uncovers the veſſel I within the nitrous air. —Such inſtrument may be alſo applied to various other experiments.

When the nitrous air is firſt produced, it appears generally red, the reaſon of which is, that then ſome ſuperfluous nitrous acid vapour is contained in it, which reddens the tincture of turnſole, combines with acids, &c.; but this vapour immediately ſubſides, eſpecially if the proceſs is made in water, in which caſe the water abſorbs it, and becomes acid, and then the nitrous air remains in its natural ſtate.

Beſides nitrous acid and phlogiſton, it is more than probable that an earth, perhaps a metallic earth, enters into the compoſition of nitrous air. The depoſit left by it in water, and even, in a ſmall degree, on the ſides of the veſſels in which it is confined by water, ſeems to ſhew it very clearly. The colour of this ſediment is not different according to the different metals that have been employed for the production of the nitrous air; and its quantity is too ſmall to render the examination of its nature eaſily practicable; nevertheleſs Mr. FONTANA has performed ſome experiments with this view. He extracted the nitrous air from iron, then agitated it in the tincture of gall-nuts, and the ſlight alteration of the colour of the ſolution ſeemed to indicate the preſence of martial earth in the nitrous air. This alteration of colour was not perceived except the veſſel, &c. was agitated, *viz.* except the nitrous air was partly decompoſed; which ſhews, that the martial earth is in a ſtate of combination with the other components of nitrous air. He alſo attempted to aſcertain the preſence of the martial earth in nitrous air, by the precipitation of Pruſſian blue; but the reſult of his experiment doth not ſeem to remove every doubt about it.—See Mr. FONTANA's *Recherches Phyſiques ſur l'Air nitreux.*

Hitherto it has not been diſcovered, that water enters into the compoſition of nitrous air; though it ſeems not improbable, that a very ſmall quantity of it might be contained in that gas.

Dr. PRIESTLEY endeavoured to aſcertain the quantity of nitrous acid, that entered into the compoſition of nitrous air, in the following manner; he decompoſed a great and known quantity of nitrous air, by mixing it with reſpirable air; and the acid vapour, which was diſengaged in this decompoſition, was abſorbed by a ſufficient quantity of water. He then eſtimated the ſtrength of this acid, *viz.* of this impregnated water, by obſerving the quantity of nitrous air that it would extract from copper, and comparing it with the quantity of nitrous air that could be produced by an equal quantity of ſtrong nitrous acid made in the common way. In one of his experiments the Doctor found, that the quantity of nitrous air produced by the former, was to that produced by the latter as 5 to 48. The impregnated water uſed in this experiment was part of the 4 ½ ounce meaſures of water, which had imbibed the acid of 300 ounce meaſures of nitrous air *.

" In order to compare the quantity of nitrous acid con-
" tained in a given quantity of nitrous air, with the quantity
" of acid contained in an equal bulk of red nitrous vapour,
" procured by the ſolution of biſmuth, I ſaturated a quan-
" tity of water, in the method deſcribed above, with as much
" of the acid as was contained in a pint phial of nitrous air;
" and having filled the ſame phial with the red vapour, I put
" into it the ſame quantity of water, to imbibe the vapour;
" and then, pouring all the water impregnated with nitrous
" acid from the nitrous air, and afterwards, that which was
" impregnated by the nitrous vapour, upon equal quantities
" of water, in a phial fitted with a ground ſtopple, I collected
" the nitrous air that they yielded, and found them to be
" exactly the ſame; and this was one ſeventh of the quantity
" of nitrous air from which the acid had been extracted; ſo
" that, provided there was no loſs of the acid in the proceſs

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* The apparatus for this experiment conſiſts of a pretty large phial, to which a cork is to be fitted, through which a hole is perforated, ſo as to admit the nozzle of a ſmall funnel, when it is thruſt in pretty hard. Then this cork is faſtened to the neck of a bladder, capable to contain about five times as much air as the phial. The nitrous air is firſt put into the bladder by means of the funnel, then removing the funnel from it, the cork is put into the glaſs phial, which, beſides the common air, contains the required quantity of water; this done, the bladder muſt be ſqueezed gradually, ſo as to let the nitrous air enter the bottle and mix with the common air, &c. In this operation, care ſhould be had to keep the bladder in ſuch a ſituation, as that any water contained in it might not fall into the phial.

" (and I am pretty well perſuaded that the loſs could not " have been at all conſiderable) it may be inferred from this " experiment, that the nitrous acid, which is detained in the " *ſalt* made by the ſolution of copper, is ſix times as much " as enters into the compoſition of the nitrous air procured " by that ſolution *."

Dr. PRIESTLEY did alſo endeavour to aſcertain, whether nitrous or inflammable air contained more phlogiſton. He mixed a known quantity of common air with a known quantity of inflammable air, and fired the mixture in a cloſe veſſel, then examined how far the remaining elaſtic fluid was phlogiſticated, by the taſte of nitrous air. Again, he mixed two known quantities of nitrous and common air, and examined alſo, by other nitrous air, how far this mixture was phlogiſticated; which, compared with the former obſervation, and after a few experiments with different proportions of elaſtic fluids, determined what quantity of nitrous air was ſufficient to phlogiſticate common air, as much as the burning of a given quantity of inflammable air. The Doctor finds, that the quantity of phlogiſton contained in a quantity of nitrous air, is about equal to the quantity contained by an equal bulk of inflammable air. " I therefore," *ſays he*, " mixed one " meaſure of inflammable with *three* meaſures of common " air, and after the exploſion found it to be ſo far phlogiſ- " ticated, that one meaſure of this and one of nitrous air " occupied the ſpace of 1.8 meaſures; and this I alſo found,

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* Exper. and Obſer. vol. iii. § 15.

" by the ſame taſte, to be exactly the ſtate to which a mix-
" ture of one meaſure of the ſame nitrous air brought three
" meaſures of the ſame common air *.

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* Exper. and Obſer. vol. iv. § 34.

CHAP. VI.

Of Marine acid Air.

HITHERTO we have treated of ſuch elaſtic fluids as could be confined by water, and the principal properties of which could be examined without the neceſſity of uſing a tub of quickſilver; but we are now going to examine another *genus* of fluids permanently elaſtic, which, different from the former, are inſtantly and in vaſt quantity abſorbed by water, and alſo by various other fluids. Quickſilver is the only fluid hitherto diſcovered, which can beſt ſerve for the examination of thoſe gaſes; and the operator muſt now make uſe of a tub of mercury, in the ſame manner as he made uſe before of a tub of water, for the examination of the permanently elaſtic fluids mentioned in the preceding chapters.

The permanently elaſtic fluids of which we are now going to treat, may be reduced to two ſpecies, viz. *acid* elaſtic fluids, which are formed by various acids exhibited in the form of air; and an alkaline air. They have ſome common properties, which we ſhall mention once for all in this place, and ſhall only take notice of ſome peculiarities of the ſame in the future chapters:—1. They are all quickly and in great quantity abſorbed by water. 2. They are highly noxious to animal and vegetable life. 3. They are incapable to aſſiſt combuſtion; and, 4. They have ſtrong, penetrating, offenſive, and peculiar ſmells.

As for the diſcovery of thoſe elaſtic fluids, and the inveſtigation of their properties, we are entirely indebted to Dr. Priestley for them. Before him, a ſlight ſuſpicion was entertained by ſome philoſophers of the production of ſome of thoſe gaſes; ſeveral circumſtances obſerved in ſome chemical proceſſes ſeeming to indicate ſuch production; but they were ſo far from being diſtinctly underſtood, that they were generally taken for vapours condenſable by cold, and therefore incapable of being examined in the elaſtic ſtate, like fixed air, inflammable air [*], &c.

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[*] That a good deal of acid, and the pureſt part of it, eſcaped in the form of a vapour from the diſtillation of ſpirit of ſalt made in the uſual manner, was known to the Chemiſts; and Mr. Woulfe invented an apparatus, the deſcription of which is inſerted in the 57th volume of the Philoſophical Tranſactions, by means of which the ſaid vapour ſhould be incorporated with water. But Mr. Cavendish, in a proceſs in which he wanted to extract inflammable air from copper,

The marine acid, when heated, produces an elaſtic fluid, which is not condenſable by the uſual cold of the atmoſphere, or indeed by any cold to which it has been hitherto expoſed; and is tranſparent like common air. As this elaſtic fluid conſiſts of the pureſt part of the acid, perhaps joined to a ſmall quantity of phlogiſton, it has been called *marine acid air*. The marine acid, after having yielded all the gas that can be obtained from it by heat, will be found to have loſt its ſtrength, ſo that it can barely corrode iron. The eaſieſt as well as the cheapeſt method of obtaining this gas, is by filling a phial (one of thoſe furniſhed with a glaſs tube and ſtopple) with common ſalt, and then pouring a ſmall quantity of ſtrong oil of vitriol upon it; which, by the aſſiſtance of a little heat, will diſengage the acid principle, or the marine acid air, from the ſalt. In fact, this is the ſame proceſs by which marine acid is extracted.—"A phial," *ſays* Dr. PRIESTLEY, "once pre-"pared in this manner, will ſuffice for common experiments "many weeks; eſpecially if a little more oil of vitriol be "occaſionally put to it. It only requires a little more heat "at the laſt than at the firſt. Indeed, at the firſt, the heat "of a perſon's hand will often be ſufficient to make it throw

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copper, by means of marine acid, found that no inflammable air was generated; yet he was perſuaded, from ſeveral circumſtances which attended the operation, that during the proceſs ſome elaſtic fluid had been generated, and had been immediately condenſed by the contact of water.—See the Philoſophical Tranſactions, vol. lvi. p. 157.

" out the vapour. In warm weather, it will even keep
" ſmoking many days without the application of any other
" heat.

" On this account, it ſhould be placed where there are no
" inſtruments, or any thing of metal, that can be corroded
" by this acid vapour. It is from dear-bought experience
" that I give this advice. It may eaſily be perceived when
" this phial is throwing out this acid vapour, as it always ap-
" pears, in the open air, in the light form of a cloud; owing,
" I ſuppoſe, to the acid attracting to itſelf, and uniting with,
" the moiſture that is in the common atmoſphere *."

This elaſtic fluid is conſiderably heavier than common air: according to Mr. FONTANA, the ſpecific gravity of it being to that of common air as five to three nearly, and a cubic inch of it weighing 0,654 grs. when the barometer is at a mean height, and the thermometer about temperate.

" Flies and ſpiders," *ſays* Dr. PRIESTLEY, " die in acid
" air, but not ſo quickly as in nitrous air. This ſurprized
" me very much; as I had imagined that nothing could be
" more ſpeedily fatal to animal life than this pure acid va-
" pour †."

When a lighted candle is admitted into a jar of this gas, its flame is extinguiſhed; but the moment before its going out, and alſo when it is afterwards firſt lighted again, it burns with a green or light-blue flame, like the flame ſeen when common ſalt is thrown into a fire.

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* Exper. and Obſer. vol. i. p. 229.

† Ibid. p. 240.

The diminution of marine acid air, occaſioned by electric ſparks, is ſo ſmall as to be juſt perceivable.

Water abſorbs a great many times its own bulk of marine acid air, till it becomes quite ſaturated with it. Dr. Priestley found, that 2 ½ grs. of rain-water abſorbed about three ounce meaſures of this gas. By this impregnation, the water becomes exceedingly acid; and indeed this impregnated water is a ſtronger marine acid than that obtained in the uſual way. It diſſolves metals much faſter, and is in every reſpect much ſuperior to the common ſpirit of ſalt. By the impregnation of marine acid air, the bulk of water is increaſed one third, and its weight is doubled; from which Dr. Priestley deduces, that two thirds of the beſt ſpirit of ſalt is nothing more than mere phlegm or water *.

The water remains tranſparent and colourleſs, even when quite ſaturated with marine acid air; and, by a very gentle degree of heat, the gas may be again expelled from it, as it is expelled from common ſpirit of ſalt.

Ice, when expoſed to marine acid air, is diſſolved by it as faſt as if it touched a red-hot iron. The gas is then imbibed by the water of the melted ice.

When marine acid air and alkaline air are mixed together, they

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* Experiments and Obſer. vol. i. p. 148.

they inſtantly combine with each other, loſe their elaſticity, and form a white viſible ſubſtance, *viz.* a neutral ſalt; but of this remarkable phenomenon proper notice will be taken in the chapter on alkaline air *.

Almoſt every ſubſtance which contains phlogiſton, when expoſed to marine acid air, occaſions a diminution of the ſame, imbibing ſome of it; and at the ſame time the gas attracting the phlogiſton from them, by which union its remaining part becomes inflammable air, which takes fire by the contact of flame, and is not abſorbable by water.—The following are the moſt remarkable particulars relating to this point, which were obſerved by Dr. PRIESTLEY. Spirit of wine abſorbs marine acid air as readily as water does. By this impregnation the ſpirit does not loſe its inflammability; its bulk is thereby increaſed, and it diſſolves iron with rapidity.

Oil of olives abſorbs marine acid air very ſlowly, and oil of turpentine abſorbs it very faſt. By this impregnation they are turned almoſt black. When thoſe oils cannot abſorb any more marine acid air, the remaining quantity of it becomes weakly inflammable, but after having been ſome time in contact with the oil; which ſeems to ſhow that this gas requires a conſiderable time before it can extract a ſufficient quantity of phlogiſton from thoſe oils.

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* No particular appearance is ſhewn by the mixture of this gas with any of the other permanently elaſtic fluids.

Eſſential oil of mint abſorbs marine acid air pretty faſt, and becomes thereby of a brown colour, conſiſtent, and ſo heavy, as to ſink in water. Its ſmell is in great meaſure altered.

Oil of turpentine becomes alſo thick and brown by the like impregnation.

Ether abſorbs marine acid air very faſt, and by that impregnation its colour is altered, becoming firſt turbid, then yellow, and laſtly brown. The permanent elaſtic fluid found over the ether in the veſſel is ſtrongly inflammable.

Vitriolic and alſo nitrous acid being admitted to marine acid air, produced no ſenſible effect.

" Iron-filings, being admitted to this air, were diſſolved " by it pretty faſt, half of the air diſappearing, and the other " half becoming inflammable air, not abſorbed by water. " Putting chalk to it, fixed air was produced *.

" The ruſt of iron, and the precipitate of nitrous air made " from copper, alſo imbibed this air very faſt, and the little " that remained of it was inflammable air; which proves, " that theſe calxes contain phlogiſton. It ſeems alſo to be " pretty evident, from this experiment, that the precipitate " above-mentioned is a real calx of the metal, by the ſolution " of which the nitrous air is generated †."

Blue vitriol acquired a ſuperficial dark colour the moment it was admitted to marine acid air, which it abſorbed very ſlowly. Green copperas abſorbed this gas very ſlowly, and

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* Exper and Obſer. vol. i. p. 149.

† Ibid. p. 150.

became of a deep green colour. White copperas abſorbed it very faſt, and was diſſolved in it.

Both the flowers of zinc and red-lead were found to abſorb a very great quantity of marine acid air. "I therefore "conclude," *ſays* Dr. PRIESTLEY, "that whether the ma-"rine acid be combined with water, or not, it has the ſame "affinity with theſe earthy ſubſtances *."

Neither ſal ammoniac nor common ſalt were affected by marine acid air.

Nitre, being expoſed to a quantity of this acid air, was preſently ſurrounded by a white fume, which ſoon filled the whole veſſel. Almoſt the whole quantity of gas was abſorbed in about a minute's time.

Alum abſorbed marine acid air almoſt as faſt as nitre, and was thereby reduced into a powder.

Camphor was ſoon reduced into a fluid ſtate, by imbibing marine acid air.

When water was admitted to it, the camphor reſumed its ſolid ſtate; its taſte was acid; and a very ſmall part of the gas was permanent and ſlightly inflammable.

Borax abſorbs marine acid air as faſt as blue vitriol, and becomes thereby whitiſh.

"White ſugar abſorbed this gas very ſlowly, was thorough-"ly penetrated with it, became of a deep brown colour, and "acquired a ſmell that was peculiarly pungent."

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* Vol. iv. p. 459.

Quick-lime, being expoſed to a quantity of this gas, left a very ſmall quantity of it unabſorbed, which was inflammable.

A piece of Derbyſhire *ſpar*, of a dark colour, was not ſenſibly affected by marine acid air.

Some pieces of ſulphur abſorbed about one fifth of a quantity of marine acid air to which it was expoſed. A ſmall part of the reſt was abſorbed by water, and the remainder was inflammable, burning with a blue flame.

Liver of ſulphur imbibed the half of a quantity of marine acid air: "one fourth of the remainder, after ſtanding one "day in quickſilver, was imbibed by water, and what was left "extinguiſhed a candle *."

About the bigneſs of a hazel-nut of bees-wax being expoſed to three ounce meaſures of marine acid air, abſorbed about the half of it in two days, and upon the admiſſion of water half of the remainder was abſorbed, leaving the reſt inflammable.

Both charcoal and pit-coal abſorb this gas very faſt, and leave the remainder inflammable.

A ſmall bit of phoſphorus ſmoked and gave light in this acid air. In about twelve hours the elaſtic fluid was little diminiſhed. Water being admitted, about four fifths of the gas were abſorbed, and the reſt was inflammable. Some ſubſtances were found not to alter the marine acid air very ſoon, but to require a conſiderable time; for inſtance, about two days. Such is dry wood, cruſts of bread not burned, dry fleſh, roaſted pieces of beef, ivory, and even flints. Theſe ſubſtances abſorb a greater or leſs quantity of marine acid air, when they are expoſed to it, and leave the remainder more or leſs inflammable.

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* Exper. and Obſer. vol. i. p. 235.—In another experiment, the gas ſuffered a greater diminution, and the liver of ſulphur, after continuing two days in the gas, began to diſſolve, and at laſt became one liquid maſs. Vol. ii. p. 233.

CHAP. VII.

Of the vitriolic acid Air, and of the Sparry or Fluor Acid Air.

THE vitriolic acid may alſo be exhibited in the form of an elaſtic fluid, tranſparent like common air, and not condenſable by the uſual cold of the atmoſphere, or by any degree of cold to which it has been hitherto applied; but whereas the marine acid air may be produced by heating the marine acid alone, the vitriolic acid air cannot be obtained, except the vitriolic acid be heated together with ſome ſubſtance that contains phlogiſton, as oil, ſpirit of wine, ether, charcoal, metals, &c.

Amongſt the ſubſtances hitherto tried, gold and platina have been found to yield no elaſtic fluid at all when heated in vitriolic acid. The other metallic ſubſtances yield more or leſs of it; and the following are the more remarkable particulars relating to the production of vitriolic acid air, which were obſerved by Dr. PRIESTLEY.

The oil of vitriol, for this purpoſe, muſt be very concentrated, eſpecially when metals are uſed; ſome of which, we have already obſerved, if diſſolved in *diluted* vitriolic acid, produce another ſpecies of elaſtic fluid, namely, *inflammable air*. The heat to be applied to the phial that contains the ingredients for the production of vitriolic acid air, muſt be regulated according to the ſubſtance mixed with the acid, the rapidity of the efferveſcence ſhewing when the heat is too much; but this degree of heat at moſt needs not be greater than that given by the flame of a uſual candle. Before any elaſtic fluid is produced, the vitriolic acid, with which the other ſubſtance is mixed, becomes very black, as phlogiſticated oil of vitriol is wont tó do; "and" *ſays* Dr. PRIESTLEY, "a quantity of this acid, thus impregnated with "phlogiſton, will yield many times more air than an equal "quantity of the ſtrongeſt ſpirit of ſalt.

"When the vitriolic acid air is produced in great plenty, "the top of the phial in which it is generated is generally "filled with white vapours. This air has alſo the ſame ap- "pearance, as it is tranſmitted through the glaſs tube; and "it is ſometimes diſcoverable in the recipient *."

When ſuch ſubſtances are put into the oil of vitriol, which cauſe a great effervеſcence with that acid, eſpecially when hot, as oil, quickſilver, &c. care ſhould be had to uſe very ſmall quantities of thoſe ſubſtances, and alſo to apply the heat by exceedingly gentle degrees; otherwiſe the rapid production of elaſtic fluid, and the heat attending it, may break the veſſels, and cauſe other damages.

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* Exper. and Obſer. vol. ii. p. 6.

When charcoal is uſed, (which ſhould be well charred for this purpoſe) the production of elaſtic fluid is more equable.

In moſt caſes this gas is produced together with ſome other elaſtic fluid, which is moſtly inflammable air, and ſometimes *fixed* or phlogiſticated air.

When ether is uſed, about one half of the firſt produce is inflammable air; but the quantity of this inflammable air leſſens in proportion to the acid air, the farther the proceſs is carried on.

Dr. PRIESTLEY obſerved, that when quickſilver was uſed, the acid was not turned black, as in other experiments of the like nature. He alſo obſerved, that iron yielded a little inflammable air together with the acid gas; but that the elaſtic fluid produced, when zinc was uſed, contained about two parts of inflammable and one part of acid air. Copper, ſilver, or lead, when put in vitriolic acid and heated, yield the pureſt vitriolic acid air, without any mixture of inflammable air; but the lead yields a very ſmall quantity of it, and requires a very great degree of heat †.

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† Exper. and Obſer. vol. ii. § 1.

Mr. FONTANA found that the ſpecific gravity of this gas is to that of common air as two to one very nearly; and that a cubic inch of it weighed 0,778 gr. the barometer being at a mean height, and the thermometer about temperate.

Water imbibes this acid air about as readily as it does marine acid air. "But," *ſays* Dr. PRIESTLEY, "water impregnated with *vitriolic acid air* differs moſt remarkably from oil of vitriol. Its acidity is now become trifling to what it was; and, from being the moſt fixed and the ſtrongeſt, it is now become the weakeſt and the moſt volatile of all acids, the ſmell of it being intolerably pungent, and almoſt the whole of it evaporating when it is expoſed to the open air.

"This great difference ſeems, however, to be wholly occaſioned by the phlogiſton ſuperadded to the vitriolic acid. This principle, united to the acid, in a manner neutralizes it, forming a kind of ſulphur, in which the acidity is in great meaſure loſt *."

Water ſtrongly impregnated with vitriolic acid air, being poured upon filings of zinc, and heated, produced a conſiderable quantity of ſtrong inflammable air.

Water will imbibe a much greater quantity of marine acid air than of vitriolic acid air; yet water ſaturated with the latter will not imbibe any of the former; though water fully ſaturated with marine acid air, will imbibe a little more of vitriolic acid air †.

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* Exper. and Obſer. vol. iii. p. 272.

Water impregnated with vitriolic acid air, whether it be expoſed to the open air or not, freezes with a degree of cold little greater than that required for the freezing of common water. Its ice ſtill retains the pungent ſmell; and, what is very remarkable, the gas does not eſcape from the water whilſt freezing, or afterwards, any ſooner than from the impregnated water that continues fluid *.

Dr. PRIESTLEY having put ſome diſtilled water, impregnated with vitriolic acid air, into a glaſs tube about two feet long, and about an inch in diameter, ſo as to fill a ſmall part of it, expoſed it to a continued heat in a furnace; and the appearances obſerved were as follows: "After continuing " about twenty days in that ſituation, the impregnated water, " which continued tranſparent to the end of the proceſs, " depoſited a ſmall quantity of black powder; and alſo a " bit of matter exactly like ſulphur, about $\frac{1}{8}$ of an inch in " diameter, lay among it. Small pieces of the ſame matter " floated on the ſurface of the liquor, and ſtreaks of the " ſame coated part of the inſide of the tube, an inch above " the liquor.

" From the top of the tube, to within about eight inches " above the liquor, were beautiful white cryſtallizations,

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† Exper. and Obſer. vol. iii. p. 276.

* Ibid. p. 362.

" like *ſpiculæ,* diſpoſed irregularly, but generally in the form " of ſtars, the glaſs being perfectly tranſparent between " them."

Theſe cryſtallizations kept continually increaſing, and often changing their places, till about four months after, when the proceſs was interrupted.

This experiment, with ſome variations, was repeated ſeveral times, the reſults being upon the whole alike. When theſe tubes were broke open under water, the water entered into them, filling about half their cavity, and the air in them was found quite phlogiſticated; " which," *ſays the Dr.* " agrees with my former obſervations of the vitriolic acid air " imparting phlogiſton to common air."

The liquor itſelf retained its acidity and pungent ſmell, which ſhews that ſome vitriolic acid air muſt ſtill remain in the water. The cryſtals were not diſſolved by this liquor; they were undiſſolved by marine acid; and, by their colour, ſmell, and flame, when burned, appeared to be true ſulphur. In conſequence of this remarkable diſcovery, the Dr. expoſed ſpirit of wine impregnated with vitriolic acid air, oil of turpentine alike impregnated, whale-oil alſo impregnated with this gas, and alſo vitriolic acid air by itſelf, to a continued heat, in glaſs tubes hermetically ſealed; and after ſome time they all ſhewed ſome incruſtations or cryſtallizations, though in a leſs degree than the tubes with the impregnated water. Vitriolic ether abſorbs vitriolic acid air about as readily as water, but is ſoon ſaturated. Its tranſparency or inflammability is not apparently altered by this impregnation. Liver of ſulphur and charcoal do alſo abſorb this air, though the ſulphur not very readily.

Their appearances are not thereby ſenſibly changed.

Vitriolic acid air is not apparently affected by phoſphorus; but the phoſphorus gives no light in this gas; its ſurface is turned black; and the ſurface of the quickſilver, that confines the jar, &c. is covered with a deep yellow or blackiſh kind of ſcum.

" Vitriolic acid air diſſolved *camphor* pretty readily, and " reduced it to a tranſparent liquor. Water being admitted " to it, the camphor reaſſumed its natural ſolid form, but " ſeemed to have acquired an acidity in its taſte †."

Borax abſorbs a pretty conſiderable quantity of vitriolic acid air, though not very read y; and by that impregnation becomes white and opaque.

Oils imbibe this gas pretty readily. Whale-oil and olive-oil were found to abſorb about ſix or eight times their bulk of it. The colour of the former became reddiſh, and the latter oil was rendered very little darker.

Nitre, *common ſalt*, *ſal ammoniac*, and *iron*, being admitted to vitriolic acid air, did not ſenſibly affect it, nor were they affected by the gas.

Common air is conſiderably phlogiſticated by remaining ſometimes mixed with vitriolic acid air; but no ſenſible diminution is obſervable to take place in this mixture. Vitriolic acid air forms a white cloud when mixed with alkaline air, as we ſhall particularly examine hereafter; but when mixed with any other permanently elaſtic fluid, it exhibits no remarkable appearances.

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† Exper. and Obſer. vol. ii. p. 13.

Dr. PRIESTLEY obſerved alſo the effects of electric exploſions in vitriolic acid air. He made the exploſions of a ſmall jar repeatedly into a ſmall quantity of this gas contained in a glaſs tube; " when," *ſays he*, " preſently the inſide of the glaſs, " through which the exploſion paſſed, was uniformly covered " with a blackiſh matter, ſo that nothing could be ſeen " through it, and the air ſeemed to be rather increaſed than " diminiſhed. Water being admitted to it, left ſo little un- " abſorbed, that it could not be examined. Part of the " blackiſh matter was waſhed off by the water [†].

" I ſaw reaſon, however, to conclude, that the whole of " the vitriolic acid air is convertible into this black matter, " but not by means of any union which it forms with the " electric fluid; but, as it ſhould ſeem, in conſequence of " the *concuſſion* given to it by the exploſion; and that, if " it be the calx of the metal which ſupplied the phlogiſton, " it is not to be diſtinguiſhed from what metal, or indeed

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[†] Exper. and Obſer. vol. ii. p. 239.—The electric ſparks, inſtead of the exploſions, had no effect.

" from what ſubſtance of any other kind, the air had been " extracted ‡."

I ſhall now deſcribe the origin, nature, and properties, of another permanently elaſtic fluid, namely, the *ſparry* or *fluor acid air*. The reaſon of inſerting it in the ſame chapter with the vitriolic acid air is, becauſe Dr. PRIESTLEY's concluſive experiments ſeem to have clearly ſhewn it to be in reality the very ſame thing with vitriolic acid air; into which it may be eaſily changed, by depriving it of an earthy part, which, when the gas is abſorbed by water, forms a ſtony cruſt upon the water, and the preſence of which earth characterizes it for the fluor acid air.

This acid gas is extracted from thoſe minerals known by the naturaliſts under the name of *fluors*, or commonly *Derbyſhire ſpar*; of which vaſes, pyramids, and other ornaments, are uſually made for chimnies *. The eaſieſt method is to put the pieces of ſpar into a phial with a ground ſtopple and tube, and to pour ſome oil of vitriol upon it. The gas will then be produced at firſt without heat, and afterwards with a very ſmall degree of heat, and may be confined by quickſilver. "The vapour," *ſays Dr.* PRIESTLEY, "as it iſſued out of "the tube into the open air, formed a permanent white "cloud, no doubt by attaching to itſelf the water that floated "in the atmoſphere; and the ſmell of it was extremely "pungent †."

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‡ Exper. and Obſer. vol. iii. p. 279.

* It is but lately that chemiſts have extracted an acid from this ſpar, by means of oil of vitriol, in the ſame manner as marine acid is extracted from common ſalt. This acid, which was diſcovered by Mr. SCHEELE, has been conſidered as of a peculiar ſort, different from the other acids, and has been called the *fluor mineral acid*; whoſe affinities are ſtated by Mr. BERGMAN in the follow- order: Fluor mineral acid, pure lime, pure ponderous earth, pure magneſia, fixed vegetable alkali, fixed mineral alkali, volatile alkali, zinc, mangeneſe, iron, lead, tin, cobalt, copper, nichel, arſenic, biſmuth, mercury, ſilver, gold, platina, pure argillaceous earth, and water.—It ſeems to be proved by Dr. PRIESTLEY's experiments, that this acid is nothing more than the fluor acid air incorporated with water, and conſequently to be originally the vitriolic acid.

From the conſideration of the phoſphoric property of the ſpar, Dr. PRIESTLEY was led to try whether Mr. CANTON's phoſphorus, which had alſo the phoſphoric property, would yield an elaſtic fluid ſimilar to that yielded by the ſpar, when oil of vitriol was poured upon it; and his ſuſpicion was verified by the reſult of actual experiment *.

It is proper for perſons, who want to produce a good deal of this gas, to be made acquainted with the following particulars; viz. that this gas, when hot, corrodes glaſs: hence, inſtead of the common glaſs phials with ground ſtopple and tube, which are often corroded through in a few minutes time, it is adviſeable to uſe common phials of the ſtrongeſt kind, to which a bent tube may be adapted; and thoſe tubes ſhould have a large bore.—This gas is eaſily produced by pouring oil of vitriol upon large pieces of ſpar; but when it is required to produce it very faſt, then the ſpar ſhould be pounded.

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† Exper. and Obſer. vol. ii. p. 190.

* Exper. and Obſer. vol. ii. p. 212.—But in his third vol. p. 287, Dr. PRIESTLEY expreſſes ſome doubt againſt the identity of the gas thus obtained, and the fluor-acid air; and he thinks the ſlight cruſt formed upon the water by the former to be, perhaps, "ſulphur formed in the ſolution, and ſublimed by "the heat of the proceſs, and not proper fluor cruſt," &c.

According to Mr. Fontana, the ſpecific gravity of this gas is to that of common air as three to one, and a cubic inch of it weighs 1,24 grs.

This gas is abſorbed by water, upon the ſurface of which a white cruſt is formed, which hinders the farther abſorbtion of the gas, except the water finds a paſſage through ſomes pores of, or breaks the cruſt firſt formed, and, riſing in proportion as the gas is abſorbed, forms a ſecond cruſt, and ſo on. This experiment often ſhews ſeveral very beautiful appearances; for the fluor cruſt breaking in different manners, and the water ruſhing through the cracks in various ways, forms a variety of incruſtations in different ſhapes. This fluor cruſt, when dried, forms a white powdery ſubſtance, which taſtes a little acid, but by waſhing it in pure water is rendered quite inſipid. Dr. Prieſtley, endeavouring to extract ſome elaſtic fluid from this fluor cruſt, by pouring oil of vitriol upon it, obtained an acid air, which was imbibed by water, but formed no incruſtation upon the ſurface of it.

Part of the water that is expoſed to fluor acid air enters into the combination of the fluor cruſt, the remainder becomes impregnated with the acid air, and this impregnation may be carried to a great degree, by ſucceſſively expoſing the ſame quantity of water to more and more fluor acid air [*]. "By the "repetition," *ſays* Dr. PRIESTLEY, "of this proceſs, an acid "liquor may be procured of a very conſiderable degree of "ſtrength. There ſeems, however, to be a limit to its "ſtrength, for the acid is exceedingly volatile, as is evident "from its extremely pungent ſmell; ſo that I have thought "that I gained nothing by repeating the proceſs more than "eight or ten times [†]."

This volatility ſeems to indicate, that the acid part is conſiderably phlogiſticated.

If to the water thus impregnated, a little degree of heat is applied, an acid elaſtic fluid is expelled from it, which appears to be exactly like the vitriolic acid air, and, beſides the other properties which it has in common with the vitriolic acid air, it is abſorbed by water without forming any fluor cruſt.

This convincing experiment juſtly determined Dr. PRIESTLEY to conſider the fluor acid air to be originally the vitriolic acid air, into which a part of the fluor earth is diſſolved and kept ſuſpended. There are, however, the following obſervations, which ſeem ſtill to ſhew ſome objection to this theory.—Firſt, the fluor acid air has ſome properties different from the vitriolic acid air; but which may be attributed to the preſence of the earth in it; ſince, when it is deprived of the earthy part, it loſes thoſe peculiar properties. Secondly, Dr. Priestley putting ſome ſpar into a quantity of vitriolic acid air, and throwing the focus of a lens upon it, endeavoured to convert the vitriolic acid air into fluor acid air; but he found, that the vitriolic acid air took up none of the ſpar by this means. Laſtly, it was obſerved alſo by Dr. Priestley, that water impregnated with fluor acid air, in order to freeze, required a greater degree of cold than the water impregnated with vitriolic acid air; but it muſt be obſerved, that water impregnated with fluor acid air does ſtill contain ſome fluor cruſt, which may perhaps prevent its freezing very ſoon *.

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[*] Upon various experiments and conſiderations, it ſeems likely that water imbibes as much of fluor acid air as it does of vitriolic acid air.

[†] Exper. and Obſer. vol. ii. p. 195.

" Ice," *ſays Dr.* Priestley, " was readily diſſolved at " firſt in fluor acid air, but afterwards very ſlowly, as might " have been concluded from the manner in which this kind " of air is imbibed by water. However, in time, the whole " of the air was abſorbed by the ice, which was diſſolved by " it, and continued upon the ſurface of the quickſilver †."

Spirit of wine and ether, both the vitriolic and the nitrous, imbibe the fluor acid air about as readily as water; but neither their inflammability nor tranſparency is altered by this impregnation.

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[*] A glaſs tube, partly filled with water impregnated with fluor acid air, and hermetically ſealed, being expoſed to a common fire, the liquor, after boiling for about one hour, ſhewed a little cloudineſs, but became again tranſparent after boiling two or three hours.—See Exper. and Obſer. vol. iv. p. 422 and 444.

[†] Exper. and Obſer. vol. iii. p. 362.

Charcoal abſorbs this gas, and contracts from it a ſtrong pungent ſmell. The *ruſt of iron* abſorbs it in like manner.

" *Alum* abſorbed this air pretty faſt, the ſurface of it be-
" ing rendered white and opaque. When it was taken out
" of the air, it looked moiſt, and was incapable of the opera-
" tion of roaſting, like that which had been expoſed to al-
" kaline air; this air having, no doubt, like the other,
" ſeized upon the water which enters into the compoſition
" of alum.

" *Quick-lime* and *chalk* both abſorbed a little of this acid
" air; but the reſult was in no reſpect remarkable. The
" latter had been diſſolved by it, and had produced a quan-
" tity of fixed air, precipitating lime in lime-water *."

Oil of turpentine, *ſulphur*, *liver of ſulphur*, *common ſalt*, *ſal ammoniac*, *iron*, or *gum lac*, being expoſed to fluor acid air, had no effect upon it.

This gas poſſeſſes the extraordinary property of corroding glaſs, when heated in contact with it. " For," *ſays Dr.*
" PRIESTLEY, " when I had filled a tube with this kind of
" air, and was endeavouring to take off different lengths of
" it with a blow-pipe, I found that, when the glaſs became
" red-hot, it was always ſo corroded and diſſolved, that it
" was impoſſible to cloſe it by ſealing †."

Fluor acid air, when mixed with alkaline air, forms a white cloud, but not ſo readily as the other acid airs.—No remarkable appearance has been obſerved by the mixture of this gas with ſome other elaſtic fluids, that have been tried.

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* Exper. and Obſer. vol. ii. p. 200.

† Ibid. vol. iv. p. 434.

As to the nature of this elaſtic fluid, it ſeems clear, that an acid, phlogiſton, and the earth of the fluor, enter into its compoſition. It ſeems alſo to be evidently proved by Dr. PRIESTLEY, that the acid part is the vitriolic, and not a particular acid; ſince, when this air is deprived of its earthy part, it appears to be the vitriolic acid air; every property hitherto obſerved of the one being alſo poſſeſſed by the other. It ſeems, therefore, that the ſpar furniſhes the phlogiſton as well as the earth; which, joined to the vitriolic acid, form that elaſtic fluid. This is farther confirmed by obſerving, that if the marine or the nitrous acid is poured upon the ſpar, the gas produced does not form any cruſt when imbibed by water; which ſeems likely to have happened, in caſe the fluor acid air was an acid *ſui generis* contained in the ſpar *. That the fluor contains phlogiſton, is evident from its forming nitrous air, when nitrous acid is poured upon it. We may laſtly conclude, as Dr. PRIESTLEY obſerved, that this gas, although originally the ſame as the vitriolic acid air, yet poſſeſſes ſeveral peculiar and very remarkable properties whilſt the fluor earth exiſts in it; and therefore in that ſtate, and on account of thoſe properties, it is entitled to the diſtinguiſhing appellation of *fluor acid air*.

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* Exper. and Obſer. vol. iii. p. 288. However Mr. SCHEELE affirms, that the cruſt is produced by diſtilling fluors with the marine or the nitrous acid.

CHAP. VIII.

Of nitrous acid Air, or Vapour.

IN the 5th chapter it was mentioned, that the nitrous air was produced by nitrous acid, and any ſubſtance containing phlogiſton ; but the nitrous acid, by itſelf, may be alſo raiſed into an elaſtic fluid by means of heat. This elaſtic fluid, however, can ſcarcely be called permanent, ſince it can hardly be preſerved pure for any length of time. Mercury is the only fluid which can confine it longer than any other fluid that has been tried ; but yet the mercury is ſoon corroded by it, and nitrous air is formed ; for which reaſon this elaſtic fluid, whoſe nature ſeems to be of great conſequence to be known, has hitherto been very imperfectly examined. I ſhall, however, relate the principal obſervations made about it ; and ſhall leave to my reader to determine, whether it beſt deſerves the appellation of *vapour*, or of a *permanent elaſtic fluid.*

The acid of nitre, heated in a phial with a glaſs ſtopple and tube, yields an elaſtic fluid, which may be received in glaſs jars filled with and inverted in quickſilver. " For " though," *ſays Dr.* PRIESTLEY, " the acid vapour very ſoon " united with the quickſilver, yet the jar in which it was

" received being narrow, the ſaline cruſt, which was formed " on the ſurface of the quickſilver, impeded the action of " the acid upon it, till I had an opportunity of admitting " water to the air that I had produced, and of ſatisfying " myſelf, by its abſorption, of its being a real *acid air*, having an affinity with water, ſimilar to other acid airs [*]."

In various proceſſes in which dephlogiſticated air is extracted from ſubſtances mixed with nitrous acid, there is a period in which neither dephlogiſticated, nor nitrous, nor phlogiſticated air is produced; but the mere vapour of nitre or nitrous acid air is produced, which is inſtantly imbibed by water. Thus, in the proceſs for obtaining dephlogiſticated air from flints, and alſo from talc, by means of nitrous acid, there is an interval between the production of phlogiſticated and of dephlogiſticated air, in which the pure acid vapour comes out [†].

Among the various methods attempted by Dr. PRIESTLEY, to expoſe this vapour or acid air to divers ſubſtances, there are two which ſeem to anſwer tolerably well. Firſt, when he wanted to mix this vapour with any other elaſtic fluid, he introduced that other elaſtic fluid in an inverted jar as uſual, then diſpoſed the apparatus ſo that the mouth of the bent tube, belonging to the phial in which the acid was contained, paſſing through the fluid into which the jar was inverted, was raiſed above the ſurface of the ſaid fluid; in which caſe the nitrous acid vapour, diſcharged from the mouth of the bent tube, came immediately into contact with the other required elaſtic fluid. In the other method, the Doctor made uſe of the apparatus repreſented by L, fig. 9, plate II. in which the acid vapour came out of the phial *a* into the phial *b*, and from this ſucceſſively through the other phials *c d*. By this means various phials could be eaſily filled with this vapour, which being heavier than common air, expelled that reſpirable fluid gradually, though not entirely, from the phials *b*, *c*, *d*; or it could be conveniently brought into contact with various fluid or ſolid ſubſtances previouſly introduced into the phials *b*, *c*, *d*. This vapour appears always of a reddiſh colour, which perhaps it never entirely loſes, except when by ſome means or other it has changed its nature; notwithſtanding which, Dr. PRIESTLEY is inclined to think, that the pure nitrous acid itſelf is as tranſparent as the other acids, and that the red appearance of the nitrous acid air is owing to a quantity of phlogiſton which is combined with it, and which is perhaps neceſſary to its aereal exiſtence.

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[*] Exper. and Obſer. vol. ii. p. 168.

[†] This vapour is alſo obtained from the ſolution of biſmuth and other metallic ſubſtances in ſtrong nitrous acid; but then it is always mixed with nitrous air.

The moſt remarkable obſervation made by Dr. PRIESTLEY, in regard to the colour of this vapour, is, that it may be made more or leſs intenſe by the action of heat only. This vapour may be confined in glaſs phials with ground ſtopples, or in glaſs tubes hermetically ſealed *, and thus may be expoſed to the fire; in which caſe it will be found, that the colour of the vapour becomes conſiderably more intenſe, in proportion as the glaſs veſſel containing it is more and more heated; and that, on the contrary, the intenſity of the colour diminiſhes in proportion as it is cooled. "It ſeems "probable, from other phenomena, that if this vapour "was not confined, but had room to expand itſelf, it "would become colourleſs with heat. This, at leaſt, is "the caſe when it is combined with water. The pheno-"mena I refer to, are very common in the proceſs for "making dephlogiſticated air, in which I firſt obſerved "them. But the ſame things are obſervable in the proceſs "for producing any other kind of air, in which much ſpirit "of nitre is made uſe of; and likewiſe, conſtantly, in the "common proceſs for making ſpirit of nitre itſelf. It is, "that when the heat is moderate, the vapour within the

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* Dr. PRIESTLEY having obſerved that red lead, impregnated with nitrous vapour, may be preſerved a long time without deliqueſcing or loſing the acid; and that, by a melting heat, it yields the acid vapour; made uſe of this ſubſtance to fill the tubes with nitrous acid vapour. "I therefore," *ſays he*, "put a ſmall quantity of this white minium into a glaſs tube cloſed at one end; "then, holding it to the fire, make it emit the red vapour, till the whole tube "is filled with it; and having the other end of the tube drawn out ready for "cloſing, as ſoon as the vapour begins to iſſue out of that end, I apply my "blow-pipe and ſeal it.

"By this means I conclude, that the tube is filled with a pure red vapour, "without that mixture of nitrous air, and perhaps common air alſo," &c.— Exper. and Obſer. vol. iv. p. 35.

" glaſs tube or retort is red; but that, as the heat increaſes, " it becomes tranſparent †."

When nitrous acid vapour is mixed with common air, a decompoſition of the latter, and a phlogiſtication of the former, take place; the air attracting the phlogiſton of the vapour, and being thereby rendered incapable of ſuffering any farther diminution from nitrous air. The time in which this effect is produced is various, according, perhaps, to the various ſtates of the vapour. In general it requires many days.

Nitrous air ſeems to be affected by nitrous acid vapour, in the ſame manner as it is affected by liver of ſulphur, viz. it is diminiſhed by it, till it loſes its power of diminiſhing common air. Dr. PRIESTLEY particularly remarks the curious appearances of this proceſs, in the following words: " The moment that the phial of nitrous air was expoſed " to this vapour, it became white, then tranſparent, then " red; and laſtly, tranſparent again *." The whole of this proceſs, viz. to the laſt diminution, does not take up more than a few minutes. " When this proceſs is quick, that is, " when the nitrous vapour comes very faſt, the whiteneſs " preceding the redneſs, on mixing the nitrous vapour with " the nitrous air, can hardly be perceived; and the veſſel

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† Exper. and Obſer. vol. iii. ſect. 18.

* Ibid. vol. ii. p. 170.

"containing the air becomes exceedingly hot, as well as the "tube through which it is tranſmitted [‡]."

Alkaline air becomes turbid, white, and is diminiſhed, by the mixture of nitrous acid vapour.—No remarkable appearance has been hitherto obſerved in the mixture of nitrous acid vapour with the other permanently elaſtic fluids, beſides thoſe mentioned above.

Water abſorbs a conſiderable quantity of this acid vapour, becoming hot, and acquiring the properties of ſpirit of nitre [*]. The following are the obſervations made by Dr. PRIESTLEY on this impregnated water: The water, after becoming warm, "began, as before, to ſparkle, and emit air; after which it "became *blue*, ſtill continuing to give air in much greater "plenty than before. After this, the water became *green*, "about which time the emiſſion of air ceaſed; and laſtly, "after the green colour had deepened very much, ſo as to "appear almoſt black, when viewed in the ſame direction "with the light that fell upon it, a *yellowiſh tinge* was "perceived to be diffuſed through the green colour; and

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[‡] Exper. and Obſer. vol. ii. p. 171.

[*] Dr. PRIESTLEY obſerves, thatt his impregnated water ſeems to be a purer acid of the kind, than the common nitrous acid; becauſe, when mixed with a ſolution of ſilver in nitrous acid, it does not occaſion the depoſition of any matter, which is the caſe when common ſpirit of nitre is uſed, and which is thought to be a proof that ſome vitriolic acid is contained in it.—Exper. and Obſer. vol. iii. p. 205.

"this was the laſt ſtate to which I could bring the water by "this impregnation [†]."

The moſt remarkable property of this impregnated water is, that the air which it yields, either with or without heat, is pure nitrous air, as good as that extracted by any means whatever, and without the mixture of any fixed air. In one experiment, Dr. PRIESTLEY obtained from a quantity of this impregnated water more than ten times its bulk of nitrous air. This will appear more extraordinary, if it be conſidered, that water cannot abſorb more than one tenth of its bulk of nitrous air [‡].

The general effects of the impregnation of oils with the nitrous acid vapour, are, a coagulation of the oil, and a change of its colour. This change of colour is not the ſame in every oil, or in the ſame period of the proceſs. Yellow, blue, orange, or reddiſh, are the uſual colours, which change according to the different nature of the oil, and the degree of impregnation. An effervefcence is generally obſerved in this impregnation of oils; and once, in an experiment with oil of turpentine, when the ſtream of nitrous vapour was peculiarly copious, Dr. PRIESTLEY obſerved a ſlight exploſion in the inſide of the phial [*]. The elaſtic fluid that may be extracted from oils thus impregnated, appears to be phlogiſticated air.

[†] Exper and Obſer. vol. iii. p. 198.

[‡] Ibid. p. 200.

[*] Ibid. ſect. 20.

When ether is impregnated with this vapour, the upper part of the phial appears filled with a white fume, and by applying a candle to the mouth of it, a green flame was perceived, like that exhibited by a mixture of inflammable and nitrous air. By a longer impregnation, the upper part of the ether aſſumes a deep blue colour, and then it emits phlogiſticated air very copiouſly. By this impregnation, ether ſeems to be rendered more volatile.

Spirit of wine does not change its colour very eaſily, when impregnated with the vapour of nitrous acid ; but after continuing the proceſs ſome time, a quantity of nitrous ether is formed, and ſwims over it.

When a copious impregnation is long continued, the ſpirit of wine at length becomes ſuddenly blue, boils, and emits a conſiderable quantity of elaſtic fluid, a greater quantity of which may be expelled from it by means of a ſmall degree of heat. "This air," *ſays Dr.* PRIESTLEY, *in one of his experiments*, "being transferred to quickſilver, did not affect it ; "and, upon admitting lime-water to it, though one half of "it was preſently abſorbed, the water did not become tur-"bid. Applying the flame of a candle to the mouth of the "veſſel in which it was contained, it burned with a blue "flame, deſcending pretty rapidly from the top to the bottom "of the veſſel *."

Alum is rendered white and opaque by nitrous acid vapour. Common ſalt imbibes this vapour. *Red-lead*, which is rendered almoſt black by nitrous acid, becomes white and brittle by the impregnation of nitrous acid vapour. It is alſo heated by that impregnation.—Sulphur is not affected by it.

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* Exper. and Obſer. vol. iii. p. 214.

Both oil of vitriol and marine acid abſorb a good deal of nitrous acid vapour, though not ſo much as water. The vitriolic acid, thus impregnated, emits a great quantity of red vapour, when water is mixed with it. The heat produced, and the impetuoſity of the vapour iſſuing, in this mixture of water with the impregnated vitriolic acid, are very remarkable phenomena. The oil of vitriol, impregnated with nitrous acid vapour, will be found almoſt entirely cryſtallized, after being kept a long but uncertain time. Theſe cryſtals, however, may be eaſily formed in the following manner :—" When the vitriolic acid is nearly ſaturated " with the nitrous vapour, hold the phial (which ſhould be " a large one, containing about a quart) and turn it ſo as to " moiſten all the inſide of it ; then immediately throw in " a very copious nitrous vapour, ſo that the whole phial ſhall " be intenſely red, and running over ; after which, put in the " ſtopper, and let it remain quite ſtill. The upper part of " the oil of vitriol will then be of an orange-colour, and all " the ſides of the phial, and eſpecially the parts towards the " bottom, will ſoon be quite covered with thoſe cryſtals, but " of different ſizes.

" By repeating this proceſs, one half of the whole body of

" vitriolic acid will be cryſtallized in an irregular manner, as " if it was congealed *."

Theſe cryſtals, when heated, produce a red fume, and become liquid; but when put in water, they become green, and efferveſce with violence, emitting bubbles of elaſtic fluid. But what is very remarkable, the water begins inſtantly to ſparkle with the ſpontaneous and copious production of very pure nitrous air; the quantity of which is equal to above one hundred times the bulk of the cryſtals †.

Water ſaturated with vitriolic acid air, may be impregnated with nitrous vapour almoſt as well as pure water ‡.

Marine acid, by the impregnation of nitrous acid vapour, acquires a deep orange-colour, and emits a vapour peculiarly pungent. Marine acid, thus impregnated, forms a moſt excellent *aqua regia*, which diſſolves gold with great rapidity, without requiring any heat, and in greater quantity than the common aqua regia. It is very remarkable, that whereas the common aqua regia conſiſts of about $\frac{1}{4}$ ſpirit of ſalt and about $\frac{3}{4}$ of nitrous acid, this new kind of aqua regia is formed by impregnating the marine acid with a very little quantity of the nitrous vapour; hence it appears, that by this method not only a ſtronger, but alſo a cheaper ſort of aqua regia may be eaſily made §.

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* Exper. and Obſer. vol. iv. § 40.

† Ibid. § 2.

‡ Ibid. vol. iii. p. 221.

§ This ſort of aqua regia may be alſo made by decompoſing nitrous air over a quantity of marine acid. Exper. and Obſer. vol. iii. p. 220.

It is very remarkable, that, after having made aqua regia by impregnating marine acid with the nitrous vapour, Dr. PRIESTLEY could not by any means form an aqua regia by impregnating nitrous acid with the vapour of ſpirit of ſalt.

When ſpirit of ſalt is ſaturated with nitrous vapour, it yields nitrous air in the ſame manner as water does.

Marine acid, ſaturated with freſh made minium, ſo as to be yellow, acquires a deep orange-colour by the impregnation of nitrous acid vapour. When ſaturated with white minium, made ſo in conſequence of the colour being extracted from it by the ſpirit of ſalt, it acquires a light-blue colour by the like impregnation. When ſaturated with precipitate *per ſe*, the impregnation of nitrous acid vapour gives it a green-colour; but renders it blue when ſaturated with flowers of zinc.

" The phoſphoric acid is preſently ſaturated with nitrous " vapour, and aſſumes a deep indigo-blue colour.

" Radical vinegar is alſo ſoon ſaturated with this vapour, " and aſſumes a light blue *."

Beſides the above-mentioned, there are a few other obſervations made in reſpect to the impregnation of ſome particular bodies with the nitrous vapour; but I ſhall not detain my reader with the particular account of the ſame, as they are of no great conſequence, and ſuch as may be eaſily imagined, after conſidering the phenomena already mentioned.

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* Exper. and Obſer. vol. iv. p. 38.

CHAP. IX.

Of Alkaline Air.

A PERMANENT elaſtic fluid, of an alkaline nature, may be obtained from volatile alkali, in the ſame manner as acid elaſtic fluids are obtained from acids.

Every volatile alkali, when heated, yields a conſiderable quantity of elaſtic fluid, which, when mild alkalies are uſed, is moſtly fixed air; but volatile ſpirit of ſal ammoniac, made by a diſtillation with ſlacked lime, contains no fixed air, and the elaſtic fluid it produces when heated, is pure alkaline air, confinable by quickſilver, tranſparent, and not condenſable into a viſible fluid by the uſual cold of the atmoſphere.

Dr. PRIESTLEY found, that the eaſieſt as well as the cheapeſt way of procuring ſuch elaſtic fluid, was to uſe the materials themſelves, out of which the volatile ſpirit of ſal ammoniac is produced. For this purpoſe, he uſually filled a phial with a mixture of one part of pounded ſal ammoniac and three parts ſlacked lime. The heat of a candle will expel a vaſt quantity of alkaline air from a phial thus filled. For common experiments, the ſame materials will laſt a conſiderable time, without any alteration. Dr. PRIESTLEY ſays, that a ſmall iron tube, to which a glaſs tube was cemented, is much more convenient for this proceſs than the glaſs phial.

“ As water ſoon begins to riſe in this proceſs, it is neceſſary, “ if the air is intended to be conveyed perfectly *dry* into “ the veſſel of quickſilver, to have a ſmall veſſel, in which “ this water (which is the common volatile ſpirit of ſal am- “ moniac) may be received. This ſmall veſſel muſt be in- “ terpoſed between the veſſel which contains the materials “ for the generation of the air, and that in which it is to be “ received *.”—See fig. xii. plate III.

Alkaline air is highly noxious to animals, and its pungent alkaline ſmell is very penetrating and diſagreeable. It is incapable to aſſiſt combuſtion, and is itſelf ſlightly inflammable. A candle dipped into a jar full of this gas, is extinguiſhed; but a little before, its flame is enlarged by the addition of another flame of a pale yellow colour ; and often the alkaline air does actually take fire when the flame of a candle is approached to it, a weak flame being ſeen to ſpread itſelf a conſiderable way about the candle, and ſometimes all through the body of the alkaline air. It is very remarkable, that the electric ſparks, when taken in alkaline air, turn it into inflammable air. The electric ſparks taken in alkaline air appear red ; but their effects upon it ſeem to be very extraordinary. Every electric exploſion, that is made in alkaline air, adds conſiderably to its bulk ; ſo that by making about 200 exploſions in a quantity of it, an addition may be made to it of perhaps a quarter of the original quantity. If water is admitted to this alkaline air, thus augmented by electricity, the original quantity of alkaline air will be abſorbed by it; and ſo much elaſtic fluid will remain unabſorbed by the water, as was added by means of the electric ſhocks. This elaſtic fluid was found by Dr. Priestley to be ſtrong inflammable air, neither affecting common air, nor being itſelf diminiſhed by nitrous air *.

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* Exper. and Obſer. vol. i. p. 166.

According to Mr. Fontana, the ſpecific gravity of alkaline air is to the ſpecific gravity of common air as 7 to 15 nearly; and a cubic inch of the former weighs 0,2 gr. when the barometer is at a mean height, and the thermometer about temperate.

Dr. Priestley found that ice was diſſolved by alkaline air as faſt as by a hot fire. "This, *ſays he*, "was tried "when the air, and every inſtrument made uſe of in the experiment, had been expoſed to a pretty intenſe froſt ſeveral hours; alſo, the water into which the ice was melted, "diſſolved more ice, to a conſiderable quantity †."

Water abſorbs a great quantity of alkaline air; and by this abſorption both its weight and bulk are increaſed. Dr. Priestley found in a ſingle experiment, upon which however he does not lay great ſtreſs, that 1¼ gr. of rain-water abſorbed ⅞ of an ounce meaſure of alkaline air, by which impregnation its weight was increaſed about half a grain, and its bulk was a little more than doubled [†]. The water thus ſaturated with alkaline air has a ſtrong penetrating ſmell of volatile alkali, and indeed much ſtronger than that of the uſual ſpirit of ſal ammoniac [‡]. Water imbibes the greateſt quantity of alkaline air almoſt inſtantly; but it requires a conſiderable time, perhaps a day or two, before it becomes ſaturated with it. After that a portion of a quantity of alkaline air has been abſorbed by water, the reſiduum is leſs abſorbable by water; which ſeems to be the caſe with every kind of permanently elaſtic fluid. From the water thus impregnated, the gas may be eaſily expelled by means of heat.

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* Exper. and Obſer. vol. ii. p. 239, 240.

† Ibid. vol. i. p. 176.

Dr. PRIESTLEY confined ſome water, impregnated with alkaline air, in a glaſs tube; and thus expoſed it to a ſtrong heat in a ſand-furnace for ſeveral days; and the effect he remarked was, a white ſediment or incruſtation on the ſides of the veſſel, and on the ſurface of the liquor [*].

Spirit of wine, or *ether*, imbibe alkaline air about as readily as water; but neither their colour nor inflammability is affected thereby. A piece of *inſpiſſated juice of turnſole*, made very dry and warm, imbibed a great quantity of alkaline air, and acquired a very pungent ſmell, but its colour was not changed. *Oil of turpentine*, *and eſſential oil of mint*, abſorbed a very ſmall quantity of alkaline air, without being affected by it. *Olive-oil* did not imbibe any. *Spirit of ſalt*, or *vitriolic acid*, imbibed alkaline air very freely; and a little quantity of a white ſalt was formed. *Phoſphorus* gives no light in alkaline air. *Alum* imbibes alkaline air, and is rendered white and opaque by it, acquiring alſo a very diſagreeable taſte. The opacity begins from its ſurface, and gradually advances towards the center of the piece of alum †. *Roaſted alum* does alſo imbibe this gas, and acquires the diſagreeable taſte by it. *Sulphur*, *nitre*, *common ſalt*, and *flints*, being admitted to alkaline air, did not produce any remarkable effect; but *charcoal*, *ſpunge*, bits of *linen cloth*, and other ſubſtances of that nature, occaſioned a diminution of the quantity of alkaline air to which they were admitted, and thereby acquired an exceedingly pungent ſmell, eſpecially the ſpunge, a piece of which, about as big as an hazel-nut, preſently imbibed an ounce meaſure of alkaline air *. Some pieces of copper having been kept a whole night in alkaline air, did not in any manner affect the gas, nor were they affected by it; which is very remarkable, conſidering that volatile alkali has a conſiderable action upon copper ‡.

[†] Exper. and Obſer. vol. i. p. 167.

[‡] By this means an alkaline liquor may be made, which is both ſtronger and cheaper than the common ſpirit of ſal ammoniac.

[*] Exper. and Obſer. vol. iv. p. 423.

The mixture of alkaline air with any of the acid gaſes, exhibits one of the moſt ſtriking phenomena in natural philoſophy; ſince two inviſible ſubſtances, on the moment they come to touch each other, loſe their elaſticity, and form a concrete white *ammoniacal ſalt.* This ſalt, when the quantities of gaſes uſed are not proportionate, ſmells very diſagreeably, either of acid or of alkaline air, according as one or the other of thoſe elaſtic fluids have exceeded the juſt proportion in the mixture. In this caſe, alſo, the ſalt eaſily deliqueſces, and evaporates in a kind of white vapour. But it does not deliqueſce when the quantities of gaſes uſed are juſtly proportioned.

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† Dr. Priestley ſuſpects, that the alkaline vapour ſeizes upon the water that enters into the conſtitution of alum.

* Exper. and Obſer. vol. i. part 2. ſect. 1.

‡ Ibid. vol. ii. p. 232.

Dr. Priestley, after having made the above-mentioned remarkable diſcovery, proceeds to aſcertain the various quantities of alkaline and of acid air that would ſaturate each other. His principal method was, to put a meaſured quantity of alkaline air into a jar filled with and inverted in quickſilver; then he added a known quantity of acid air, which formed a white ſalt, both elaſtic fluids nearly loſing all their elaſticity. Thus, by varying the quantity of one gas in proportion to the other, he aſcertained, after various trials, the quantities both of the alkaline and the acid gaſes, which, when mixed together, and after forming the ſaline ſubſtance, would leave the leaſt reſiduum under the form of permanently elaſtic fluid. By this means the Doctor found, that equal quantities of alkaline and marine acid air would ſaturate each other, forming the above-mentioned neutral ſalt, containing marine acid and volatile alkali; but after this ſaturation, a reſiduum of elaſtic fluid remained, which was unabſorbable by water, and which, by the nitrous taſte, appeared to be little inferior to common air. Two meaſures of alkaline air would ſaturate one meaſure of vitriolic acid air, forming a neutral ſalt, and entirely loſing their aereal form *. The Doctor at the ſame time obſerved, that as much fluor acid air was required to ſaturate a quantity of alkaline air, as of vitriolic acid air, viz. two meaſures of the alkaline air for one of the fluor acid air; which, as the Doctor juſtly remarks, is a ſtrong argument to evince the ultimate identity of the vitriolic acid air, and the fluor acid air.

"Laſtly," *ſays he*, "I filled the veſſel, in which I had mea-
"ſured the preceding kinds of air, with *red vapour of ſpirit of*
"*nitre*, and put to it an equal quantity, and one fourth more,
"of alkaline air; when it immediately became very turbid and
"white, and the quickſilver roſe within the veſſel. Then
"filling the ſame phial again with the red vapour, as nearly
"as I could in the ſame manner, and admitting water to
"it, one fourth of the contents of the phial was abſorbed.
"This, therefore, muſt have been the ſpace that would have
"been occupied by the pure nitrous vapour, if there had
"been no common air mixed with it. Conſequently, one
"meaſure of nitrous vapour, in fact, ſaturated about five
"meaſures of alkaline air †."

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* "There was frequently, however, the appearance of ſulphur produced, "upon the mixture of alkaline air with vitriolic acid air; for the inſide of the "tube would be covered with a perfectly yellow matter. But this colour goes "off in time, and nothing but a white ſaline ſubſtance remains."—Exper. and Obſer. vol. ii. p. 22.

† Exper. and Obſer. vol. iii. p. 293.

One meaſure of fixed air was found to ſaturate about three meaſures of alkaline air, forming ſlender cryſtals, which croſſed each other, and formed a kind of net-work on the ſides of the veſſel; but the mixture of thoſe two gaſes is not made ſo quickly as the others mentioned above. —Nitrous air being admitted to alkaline air, occaſioned a whitiſh cloud, and a little diminution took place; but it ſoon grew clear again, leaving a little dimneſs on the ſides of the veſſel. The mixture of alkaline air with the other ſorts of elaſtic fluid, did not ſhew any remarkable appearance.

In another ſet of experiments, Dr. PRIESTLEY admitted equal meaſures of the acid airs to a large quantity of alkaline air, obſerving, by the diminution which took place, how much of alkaline air would be ſaturated by equal quantities of the acid airs; and theſe diminutions he found to be in the following proportion [†]:

A meaſure of fluor acid air abſorbed of alkaline air	$1\frac{19}{20}$
A meaſure of vitriolic acid air - - -	2
A meaſure of marine acid air - - -	$1\frac{1}{6}$
A meaſure of fixed air - - - -	$1\frac{6}{7}$

This way of making the experiment, the Doctor remarks, to be leſs accurate than the preceding; and indeed, conſidering that thoſe elaſtic fluids cannot be always obtained of preciſely the ſame goodneſs, and alſo that ſome difference may be occaſioned by the manner of mixing them, it ſeems impoſſible to obtain much accuracy in experiments of this ſort.

[†] Exper. and Obſer. vol. iii. p. 294.

CHAP. X.

Containing the deſcription of ſome other permanently elaſtic Fluids, various promiſcuous particulars, and the properties of Charcoal.

IN the preceding chapter, thoſe permanently elaſtic fluids have been treated of, the nature and properties of which had been in great meaſure examined; there are, however, ſome few others, viz. the *vegetable acid air*, the *hepatic air*, and another elaſtic fluid, obtained by means of aqua regia from certain metals, which perhaps is a fluid diſtinct from the reſt; but, as the known particulars of theſe are very few and imperfect, it was deemed more proper to mention them in this ſingle chapter, than to employ a ſeparate chapter for the deſcription of each of them. Various other properties of elaſtic fluids in general will be alſo mentioned in this chapter, ſome of which have not been taken notice of in the preceding pages; though others have been already noticed, but of which a collective view ſeemed to be neceſſary, in order to compare one of them with the other: ſuch are the ſpecific gravities of elaſtic fluids, &c.

Dr. PRIESTLEY, who has been the indefatigable promoter of this ſubject, attempted to exhibit alſo the vegetable acid in the form of a permanently elaſtic fluid. By means of heat only, he obtained from very ſtrong concentrated acid of vinegar, an acid elaſtic fluid, confinable by quickſilver, and which extinguiſhes the flame of a candle without any particular appearance. In this proceſs, he made uſe of the apparatus delineated plate III. fig. xii. it being neceſſary to have a ſmall phial between the phial with the acid and the quickſilver, in which the acid that boils over might be lodged, in order to obtain the *vegetable acid air* free from moiſture [*]. This elaſtic fluid ſeems to be weaker than any of the mineral acids; ſince it made no impreſſion upon common ſalt, or borax; and, in ſhort, it was found unable to decompoſe any ſubſtance, into the compoſition of which any of the mineral acids entered [†].

Water imbibes vegetable acid air as readily as any of the other acid airs [†].

Olive-oil abſorbs a conſiderable quantity of vegetable acid air, and pretty readily. By this abſorption, the oil loſes its natural yellowiſh colour, and becomes quite tranſparent; which is rather remarkable, ſince oil in general, by being impregnated with any of the other acid airs, is rendered both more viſcid and darker *. Oil of turpentine acquires a yellow tinge from vegetable acid air †.

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[*] Exper. and Obſer. vol. ii. p. 23.

[†] Ibid. p. 25.

" *Charcoal* imbibes vegetable acid air very faſt, and after-
" wards the ſmell of it is exceedingly pungent; but the air
" which remains ſeems not to have been altered by any thing
" that it had got from the charcoal ‡."

Liver of ſulphur imbibes vegetable acid air ſlowly, and without any particular appearance ‡.

Common air is phlogiſticated by vegetable acid air, ſo as to extinguiſh a candle §.

Vegetable acid air, like any of the other acid airs, loſes its elaſticity, and forms a white cloud, when mixed with alkaline air. " The ſides of the veſſel," *ſays Dr.* PRIESTLEY, " in
" which this mixture was made, were tinged with yellow, as
" in the ſame proceſs with vitriolic acid air; which to me is a
" puzzling fact, as I do not know that ſuch a ſulphur (if the
" ſubſtance be ſulphur) was ever known to be formed with-
" out the vitriolic acid ||."

In the 17th ſection of his ſecond volume of Experiments and

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* Exper. and Obſer. vol. ii. p. 28.

† Ibid. p. 326.

‡ Ibid. p. 25.

§ Ibid. p. 27.—Common air was alſo found to be completely phlogiſticated, after ſome weeks, by liquid vegetable acid.

|| Exper. and Obſer. vol. ii. p. 24.

and Obſervations, Dr. PRIESTLEY remarks, that the vegetable acid air bears great reſemblance to the vitriolic acid air; and that, if the difference of the effects produced by them upon olive-oil, and alſo their different *ſmell*, be excepted, they ſeem to coincide in the other properties. But he judiciouſly ſubjoins the following ſuſpicion: "As Dr. HIGGINS," *ſays he*, "has informed me, that oil of vitriol was employed in "preparing the concentrated vinegar that I made uſe of for "the production of vegetable acid air, I think it poſſible, that "the air which I expelled from it may have been, in part, "of the vitriolic kind; but I do not know of any other "vegetable acid liquor that will yield air, at leaſt in a "quantity ſufficient for any experiments."

Conſidering theſe remarks, and alſo Mr. FONTANA's diſcovery of the nature of vegetable acids, (the acidity of which Mr. FONTANA found to be owing to fixed air, &c.) it ſeems not unlikely, and Dr. PRIESTLEY himſelf ſuſpects it, but that no ſuch thing as vegetable acid air, different from the other elaſtic fluids, exiſts in nature.

The *hepatic air*, ſo called on account of its ſmell, which reſembles the ſmell of *hepar ſulphuris*, *liver* of *ſulphur*, is mentioned by Mr. BERGMAN, in his excellent diſſertation on the mines of zinc, § 8 and 9. He obtained this elaſtic fluid from a mineral called *Pſeodogalena nigra Dannemorenſis* *. One hundred parts of this mineral were found by Mr.

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* Some other ores of zinc yield alſo this elaſtic fluid.

BERGMAN to contain 29 parts of ſulphur, one of regulus of arſenic, 6 of water, 6 of lead, 9 of iron, 45 of zinc, and 4 of ſiliceous earth.

When oil of vitriol is poured upon this powdered mineral, the hepatic ſmell is immediately perceived, and a ſmall quantity of hepatic air is produced. Marine acid expels a much greater quantity of hepatic air from this mineral than the vitriolic acid. By means of diluted nitrous acid, nitrous air was only obtained. This hepatic air was confined by quickſilver, and when an equal quantity of nitrous air was mixed with it, a condenſation took place, and a depoſition of a quantity of ſulphur *; but Mr. BERGMAN ſeems not to have aſcertained any other property of it. He remarks, that it could not be a liver of ſulphur; ſince neither an alkali, nor an abſorbent earth, was found to exiſt in this mineral; and he imagines that this elaſtic fluid is a compound of ſulphur, of phlogiſton, and of the element of heat.

An acid air, in ſome meaſure different from the other acid elaſtic fluids, was obſerved by Dr. PRIESTLEY, and deſerves to be farther inveſtigated. The Doctor's paſſage is the following: "But none of the appearances recited above are ſo "remarkable as the phenomena produced by the vapour "which I procured on diſtilling to dryneſs a ſolution of gold

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"* Aeris hepatici dimidius quadrans in lagena inverſa collecti, aere nitroſo "æqualis voluminis intromiſſo, mox congrumatur ſulphur deponens, & hydrar-"gyrus thermometri, in eodem ſuſpenſi, per 6 gradus aſcendebat."

" in marine acid, impregnated with nitrous vapour, which I " have mentioned as ſo excellent a kind of *aqua regia.* The " produce of this proceſs was an *acid air* of a very peculiar " kind, partaking both of the nitrous and marine acid, but " more of the latter than of the former, as it extinguiſhed a " candle; but it was both extinguiſhed and lighted again " with a moſt beautiful deep blue flame. A candle dipped " into the ſame jar of this kind of air, went out more than " twenty times ſucceſſively, making a very pleaſing experi" ment. The quantity of this acid air is very great, and the " reſiduum I have ſometimes found to be dephlogiſticated, " ſometimes phlogiſticated, and at other times nitrous " air *."

I ſhould have hardly mentioned this as a ſuſpicion of the exiſtence of a new ſort of elaſtic fluid, had not Mr. FONTANA mentioned to have diſcovered a new permanently elaſtic fluid to be obtained from gold and platina. A ſhort time before he left London, he ſaid to have diſcovered this elaſtic fluid, and to have aſcertained its properties, which were very remarkable; but he was unwilling to make thoſe particulars known at that time, and I never afterwards learned any thing farther about them.

The ſpecific gravities of the divers permanently elaſtic fluids having been mentioned in the preceding chapters in a ſeparate manner, I think it very proper to collect them in one point of view, in order that the proportion of one to the other may be eaſily perceived. The following table exhibits thoſe gravities, and alſo the abſolute weights of a cubic inch of the various elaſtic fluids, under a mean height of the barometer and temperate degree of heat; which are the reſults of Mr. FONTANA's experiments, whoſe method of aſcertaining them is certainly the moſt exact.

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* Exper. and Obſer. vol. iii. p. 225.

Names of elaſtic Fluids.	Their ſpecific gravities.	Weight of a cubic inch of, in grains.
Common air	152	0,385
Dephlogiſticated air	160	0,042
Phlogiſticated air *	140	0,377
Fixed air	220	0,57
Inflammable air	10	0,035
Nitrous air	157	0,399
Marine acid air	243	0,654
Vitriolic acid air	300	0,778
Fluor acid air	450	1,24
Alkaline air	70	0,2

Dr. PRIESTLEY endeavoured to aſcertain the various expanſions or additions of bulk made to equal quantities of different elaſtic fluids by equal degrees of heat; and he found, that whilſt the thermometer was heated of ten degrees, the

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* The air was phlogiſticated by ſaturation with nitrous air.

expanſions of equal quantities of elaſtic fluids, heated alſo of ten degrees, were as in the following table *:

Common air	1,32	Nitrous air	2,02
Dephlogiſticated air	2,21	Marine acid air	1,33
Phlogiſticated air	1,65	Vitriolic acid air	2,37
Fixed air	2,20	Fluor acid air	2,83
Inflammable air	2,05	Alkaline air	4,75

I ſhall not detain the reader with an account of the method uſed in thoſe experiments, ſince it ſeems not to be capable of much preciſion, and the Doctor himſelf does not lay great ſtreſs upon the above-mentioned reſults.

Some perſons ſeem to have ſuſpected, that the other permanently elaſtic fluids had not the ſame mechanical property that common air has, viz. of occupying a ſpace inverſely proportional to the weights that confine it. But this ſuſpicion has never been verified by experiments; on the contrary, beſides it appearing very unlikely, fixed air, and one or two more elaſtic fluids, having been examined after the manner uſed for common air, and deſcribed in the preceding Part of this work, have been found to be exactly like common air in this reſpect, viz. to be confined into ſpaces inverſely proportional to the weights that confine them.

Dr. PRIESTLEY finds that every kind of permanently elaſtic fluid is a non-conductor of electricity; but probably they

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* Exper. and Obſer. vol. iii. p. 347.

are not all of the ſame degree. The colour of the electric ſpark, although equally viſible, yet is not of the ſame colour in every ſort of elaſtic fluid. In inflammable, and in alkaline air, it appears of a purple or red colour; in fixed air it appears white.

I ſhall, laſtly, conclude this chapter, and this Part of my work, with the account of Mr. FONTANA's remarkable diſcovery relating to ſome properties of charcoal.—That various ſubſtances had the property of diminiſhing and of abſorbing common air, and ſome other permanently elaſtic fluids, eſpecially when theſe ſubſtances had been heated previous to their being expoſed to the air, &c. had been obſerved by various philoſophers. But the quantity of common air thus abſorbed was very inconſiderable, and always a reſiduum was left. Mr. FONTANA, as early as the beginning of the year 1776, being at Paris, ſhewed to ſeveral perſons his diſcovery of a ſubſtance that in certain circumſtances could abſorb a quantity of common air ſeveral times greater than its own bulk, and that without leaving any reſiduum of air, provided the quantity of air to which that ſubſtance was expoſed did not exceed the quantity poſſible to be abſorbed. In ſhort, Mr. FONTANA found that *charcoal* (whether it had been made by charring a piece of wood ſlowly without flame, or it had been ſuffered to flame) after it had been made red-hot, in the act of cooling abſorbed a quantity of common air equal to about ſix, and often even eight times its own bulk; ſo that if a piece of red-hot charcoal was confined under a glaſs jar filled with common air and inverted in quickſilver, and if the bulk of the air contained in the jar was not above ſix times the bulk of the piece of charcoal, that quantity of air would be gradually abſorbed, and by the time the charcoal was become cold, the whole quantity of air would have diſappeared, and conſequently the jar would be entirely filled with quickſilver. The moſt remarkable circumſtance is, that the charcoal once made red-hot, and extinguiſhed out of the contact of air, viz. in vacuo, or in quickſilver, never loſes the property of abſorbing air; at leaſt Mr. FONTANA found, that the charcoal retained it undiminiſhed even after ſeveral months; ſo that if a piece of red-hot charcoal be plunged in quickſilver, and be kept therein for any length of time; or if it be put into a receiver out of which the air is quickly exhauſted before the charcoal loſes entirely its redneſs; and if afterwards this piece of charcoal, ſo preſerved either in vacuo or in quickſilver, be expoſed to a quantity of air not exceeding ſix times its own bulk; the air will be entirely abſorbed by it, without leaving any reſiduum. When the charcoal thus preſerved is expoſed to a proper quantity of common air, the quantity of air is abſorbed inſtantly, affording a very pleaſing ſpectacle; whereas, when the red-hot charcoal is uſed, the air is abſorbed gradually, viz. as the charcoal cools. Sometimes, when the experiment is made in the uſual manner, viz. in a glaſs jar inverted in quickſilver, and with one or more pieces of charcoal extinguiſhed in mercury, the air is abſorbed ſo faſt, and the mercury with the charcoal ſwimming upon its ſurface riſes ſo quickly, that the glaſs jar has been actually broken by the charcoal being violently impelled againſt its inverted bottom.—If the quantity of common air is greater than that poſſible to be abſorbed by the charcoal, the reſiduum will be found to be ſenſibly phlogiſticated.

As ſome of my readers may perhaps be at a loſs to perform this remarkable experiment, I ſhall here add proper inſtructions for the particular method of performing it.—Let one or more roundiſh pieces of charcoal be made thoroughly red-hot in a common fire, then take them one by one with a pair of iron tongs, the extremity of which ſhould be alſo made nearly red-hot, that they might not cool the charcoal; and, plunging the charcoal entirely into the tub of quickſilver, let it reſt under the ſhelf, and remove the tongs. The charcoal in this manner will be cooled, and preſerved out of the contact of air. Now, when the abſorption of air is required to be ſeen, invert a glaſs jar into the quickſilver, and let the quantity of air contained in it be, by gueſs, not above ſix or ſeven times the bulk of the charcoal preſerved under the ſhelf; then hold the jar with one hand, and with the other lay hold of the charcoal, and, taking care not to raiſe any part of it above the ſurface of the quickſilver, bring it under the jar, which muſt be wider than the piece of charcoal; and then letting it go, the charcoal will ſwim upon the quickſilver into the jar, and will abſorb the whole quantity of air contained in it.

The charcoal that has been thus extinguiſhed in quickſilver, will be found wholly penetrated by that metallic fluid; and if, being broken tranſverſely, it be viewed through a magnifier, its minuteſt pores appear full of ſhining mercury, and exhibit a moſt beautiful injection.—By pounding the charcoal, the mercury may be all ſeparated from it.

Mr. FONTANA could not find any other fluid beſides quickſilver, in which a red-hot charcoal being extinguiſhed, might not be deprived of the property of abſorbing air when afterwards preſented to it. If the red-hot charcoal is extinguiſhed in water, or in oil, it generates ſome inflammable air, a greater quantity of which is obtained when oil is uſed, than when water; but in both caſes the charcoal loſes its property of abſorbing air.

Mr. FONTANA alſo obſerved, that charcoal, in the above-mentioned circumſtances, would abſorb every other permanently elaſtic fluid, beſides common air; that by means of heat the charcoal would afterwards yield again the elaſtic fluid, though this was not of the ſame nature as that abſorbed:—but at the ſame time that he gave me leave to publiſh the above-mentioned particulars, he ſeemed unwilling to acquaint me with the reſt *.

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* Dr. PRIESTLEY, in conſequence of being made acquainted with theſe remarkable diſcoveries of Mr. FONTANA, made the following experiment:—“ I “ dropped,” *ſays he*, “ a piece of red-hot charcoal into a phial of nitrous air, “ and

This property of charcoal, Mr. FONTANA thinks to be owing to a quantity of phlogiſton, which is retained by the charcoal when extinguiſhed in vacuo or in quickſilver, but which is imparted to the oil and to the water, and alſo forms the inflammable air, when the charcoal is extinguiſhed in oil or in water; and accordingly, in thoſe caſes, the charcoal loſes its property of abſorbing air, when it is afterwards expoſed to that element.

Upon this property of charcoal, Mr. FONTANA imagined that an exhauſting-engine might be eaſily conſtructed, which would anſwer much better than the beſt air-pumps now uſed, eſpecially becauſe the charcoal abſorbs alſo the moiſture of the air; ſo that if a piece of charcoal abſorbs a quantity of air contained in a glaſs veſſel, the ſides of the veſſel remain quite dry; which is not the caſe with the common air-pumps. A few experiments that I made ſome time ago ſeem to ſhew, that when the preſſure of the atmoſphere is removed, the charcoal does not abſorb the whole of a conſiderable quantity of air, as of about three or four times its own bulk; which

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" and immediately inverting it into a baſon of mercury, the air was preſently " reduced to one fifth of the whole. Thus it continued two months, without " any ſenſible change; after which I found, that the air that remained un- " abſorbed did not affect common air, nor did the air that was emitted by the " charcoal, when it was plunged in water; ſo that, in both theſe caſes, the air " ſeemed to be entirely deprived of its peculiar properties, and to become mere " phlogiſticated air."—Exper. and Obſer. vol. iv. p. 454.

Mr. FONTANA alſo ſuſpected: yet it is not improbable, that with a great quantity of charcoal, and a comparatively ſmall quantity of air, the whole of that fluid might be completely exhauſted from a receiver, when the preſſure of the atmoſphere is out of the queſtion; and therefore it is ſtill to be wiſhed that ſuch an exhauſting engine were tried.

PART IV.

Containing the Uſes, Theory, and various other Particulars relating to, and ſome Experiments of the Author on the Subject of Fluids permanently elaſtic.

IN the preceding Part, the various properties of permanently elaſtic fluids, their origin, and their nature, have been ſufficiently deſcribed; but in this laſt Part of the preſent work ſeveral particulars will be mentioned, which, although relating to the ſubject, yet ſeemed not proper to be inſerted among the preceding chapters: ſuch are—the nature of mineral waters—the nature of fulminating ſubſtances—the theory of elaſtic fluids—the advantages derived from the ſubject, &c. Laſtly will be added, a ſhort account of ſome new experiments made by the author.

CHAP.

CHAP. I.

Of the elaſtic Fluids of Mineral Waters.

IT is not my deſign to examine, in this chapter, the various ingredients and medicinal properties of the various mineral waters, ſince that is both foreign to my ſubject, and treated of by various authors who have expreſsly written upon the nature and properties of thoſe waters; but I ſhall only mention, in a ſuccinct and ſummary way, the more intereſting particulars relating to the elaſtic fluids contained in many mineral waters, and to which ſome of thoſe waters owe their greateſt medicinal powers.

The elaſtic fluids extracted from mineral waters are of three ſorts, namely, *fixed air*, *inflammable air*, and *phlogiſticated air*. Often one or two, and ſometimes all three of theſe elaſtic fluids are found together in the ſame mineral water. Their modes of exiſtence in thoſe waters are alſo various, both in reſpect to quantity, and intimacy of combination; for ſometimes they are ſo looſely mixed with the water, that by mere expoſure to the open air they eſcape in a ſhort time; and on the contrary, in other caſes, a very long boiling is hardly ſufficient to expel them *. Indeed Mr. De

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* It has been ſhewn in the preceding pages, that the gas is more obſtinately retained in water when another ſubſtance is combined with it; both which ſubſtance

Luc has ſhewn, that a ſmall quantity of air is always retained by water, even after a long boiling; and which quantity of air, or other elaſtic fluid, cannot be ſeparated from the water, except by means of a long-continued agitation in vacuo; and perhaps not even then entirely. It ſeems, that ſometimes the elaſtic fluid is looſely mixed with the water, or with ſome other ſubſtance contained in it; but that in proceſs of time their union becomes more intimate, and conſequently the elaſtic fluid cannot be eaſily ſeparated from the water; for Dr. J. Keill found, that a certain mineral water loſt its ſpirituous or ſparkling property by being kept in a *Florence* flaſk hermetically ſealed for a conſiderable time.—The following is a very remarkable obſervation of Dr. Brownrigg, relating to the eſcape of the gas from a mineral water: The Doctor found that *Pohun water* loſt its gas very ſoon, when expoſed to the open air; but that when the ambient air was intercepted from the ſaid mineral water, the gas, which might have aſcended into an empty bladder that was tied to the mouth of the veſſel, was ſo obſtinately retained by the water, that neither in the hotteſt weather, would eſcape from it *.

The quantity, as well as the quality, of the gas contained in the medicinal mineral waters is different; though as to the quality, it is in general fixed air; at leaſt this is the only elaſtic

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ſtance and gas ſeem to detain each other mixed with and ſuſpended in the water. Hence, when the elaſtic fluid is ſeparated from certain mineral waters, a depoſition of an earth, or other ſubſtance, takes place.

* Phil. Tranſ. vol. lxiv.

fluid which, when combined with water, has been found to be beneficial: ſo that the mineral waters, which abound with other ſorts of elaſtic fluid, are ſeldom, if at all, uſed in medicine, except when their medicinal powers are owing to ſome other ingredient. Some mineral waters are thought to contain little or nothing elſe beſides fixed air, to which they owe their ſparkling property and medicinal qualities; whereas others contain a very inconſiderable quantity of gas, and conſequently are medicinal on account of other ſubſtances that are contained in them. It may be, indeed, that they contain a great deal of gas, but in ſo intimate a combination with other ſubſtances, that even a long boiling is inſufficient to manifeſt its preſence *. This perhaps may be the caſe with the *Bath* water; which Dr. PRIESTLEY found to yield not above one thirtieth of its bulk of elaſtic fluid, which conſiſted of half fixed and half phlogiſticated air.—The Doctor boiled the ſaid water for above four hours, and received the produced elaſtic fluid in quickſilver †.

Common well-water, by boiling, yields not above one ſixtieth of its bulk of elaſtic fluid, which generally is air ſlightly phlogiſticated; but waters of this kind are ſubject to a great diverſity. As to the elaſtic fluid obtained by various means from river-water, ſea-water, &c. ſufficient notice has been taken in the preceding pages. The quantity of gas, that boiling will force out of mineral waters in general, does ſeldom amount to one fourth of the bulk of the water *.

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* Acids ſometimes will expel more elaſtic fluid from certain mineral waters, than a very long boiling.

† Exper. and Obſer. vol. ii. p. 222.

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* Mr. CAVENDISH obtained above 75 ounce meaſures of gas from 411 ounces of *Rathbone-place water*; and he obſerves, that about twenty ounce meaſures of this elaſtic fluid was yielded before the water boiled. Phil. Tranſ. vol. lvii.—Dr. HALES obtained two cubic inches of elaſtic fluid from 54 cubic inches of *Pyrmont water.*—Mr. VENEL ſays, that *Seltzer water* contained one fifth of its bulk of elaſtic fluid, and that neither an acid nor an alkaline principle was contained in it, beſides the ſaid elaſtic fluid. But the beſt analyſes of thoſe two principal mineral waters, viz. the Pyrmont, and the Seltzer water, were lately made by that great chymiſt Dr. B. HIGGINS; which are as follows:

“ A Wincheſter gallon of Pyrmont water contains,

	dwts.	gr.
“ Of calcareous earth, combined with vitriolic acid, in the form of ſelenite — — — —	2	13,2
“ Of calcareous, earth combined with acidulous gas — —	1	22
“ Of magneſia, combined with acidulous gas — —	0	16,6
“ Of iron, combined with acidulous gas — —	0	2,6
“ Of magneſia, combined with vitriolic acid, or of bitter cathartic ſalt — — — —	1	6,7
“ Of ſea ſalt — — — —	0	10,1

“ It likewiſe contains 192 ounce meaſures of acidulous gas, excluſive of “ the quantity retained in the heat of boiling water, by the calcareous earth, “ magneſia, and iron, and one ounce meaſure of atmoſpheric air.

“ A Wincheſter gallon of Seltzer water contains,

	dwts.	gr.
“ Of calcareous earth, combined with acidulous gas —	0	14
“ Of magneſia, combined with acidulous gas — —	0	20,5
“ Of mineral alkali, weighed in the cryſtalline form —	5	21,6
“ Of ſea ſalt — — — —	3	20,2
“ Of mineral oleaginous matter — — —	0	0,2

The medicinal qualities of ſeveral mineral waters have been known long before any diſtinct idea had been acquired of the nature of fixed air, which is the principle that moſt of all gives the medicinal quality to the water. The more common idea was, that a volatile ſpirit exiſted in the waters, the nature of which was various. HOFFMAN ſaid, that ſome of the mineral waters of Germany contained a *ſulphureous aereo ethereo elaſtic ſpirit*. VAN HELMONT was ſo far acquainted with the nature of the mineral waters, that he plainly attributes the depoſition of ferruginous matter, and the loſs of the acidulous taſte of the mineral waters, when expoſed to the open air, to the eſcape of the gas from them.

The attempts to imitate ſome mineral waters have not only been practiſed, but have even in great meaſure ſucceeded, long before fixed air was known. I remember to have read, in ſome old book containing the deſcriptions of various remedies, the detail of divers proceſſes to make artificial mineral water; which, however, were neither founded upon theory nor anſwered upon practice. In the year 1750, Mr. VENEL endeavoured to imitate the Seltzer water, by adding to it ſome mineral alkali and marine acid; by which means the gas, ſeparated from the alkali by the acid, impregnated the water,

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" It likewiſe contains 128 ounce meaſures of acidulous gas, excluſive of the
" quantity retained in the heat of boiling water, by the calcareous earth,
" magneſia, and mineral alkali, and an ounce and half meaſure of atmo-
" ſpheric air."

and gave it the ſparkling quality. In the year 1736, one Dr. SEYP of Pyrmont advanced, that the elaſtic fluid of this mineral water was of the ſame nature with that of the *Grotto del Cane*; and in the 55th vol. of the Phil. Tranſ. there is a paper of Dr. BROWNRIGG, in which the author ſays, that the elaſtic fluid contained in the waters of Spa and Pyrmont, was of the ſame nature with that which conſtituted the choke-damp in mines. Mr. CAVENDISH obſerved, that the gas of *Rathbone-place* waters precipitated lime in lime-water; hence he ſuppoſed, that the greateſt part of it was of the ſame nature with the gas of calcareous earths. But Dr. PRIESTLEY was the firſt who ſhewed the ready and elegant way of impregnating water with fixed air, and brought the ſubject of making artificial mineral waters to the advanced ſtate, of which notice has been taken in the preceding Part of this work.

CHAP. II.

Of fulminating Subſtances.

VARIOUS ſubſtances, when heated to a certain degree, produce a great quantity of elaſtic fluid, and almoſt inſtantaneouſly; which elaſtic fluid gives a concuſſion to the ambient air, occaſioning an exploſion; for which reaſon the ſubſtances that produce it are ſaid to *explode*, or to *fulminate*. It is owing to the production of the elaſtic fluid, that bodies which confine the fulminating ſubſtances at the time of their exploding are broken, diſtended, propelled, or, in ſhort, receive the efforts of the produced elaſtic fluid. It is evident from this, that the impetus, or the force exerted, and the report, is in proportion to the quantity of elaſtic fluid produced, and alſo to the quickneſs of this production.

The various fulminating ſubſtances may be conſidered to be of two ſorts, viz. thoſe into the compoſition of which *nitre* enters, and ſome metallic precipitates. The principal of the former ſort are *gun-powder*, and *fulminating-powder* *; thoſe of the latter, are *fulminating-gold*, and ſome mercurial precipitates, which Mr. BAYEN diſcovered to have this property when they were triturated with about one ſixth part of flowers of ſulphur, and then heated. The principal of thoſe precipitates are the following:

" Precipitates made by adding a *fixed alkali*, *mild* or " *cauſtic*, or a *volatile mild alkali*, or *lime-water*, to a ſolu- " tion of *mercury* in nitrous acid.

" Precipitates made by adding *fixed alkalies*, *mild* or *cauſ-* " *tic*, or *lime-water*, to a ſolution of *corroſive ſublimate* in " water.

" A precipitate or *mercurial calx*, prepared by digeſting " in a ſand-bath, *turbith mineral*, with a ſolution of *fixed al-* " *kali* in water, till the precipitate became red.

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* Nitre deflagrates with combuſtible matters in general.

"Mr. BAYEN remarks, that no detonation was produced "by mixing theſe precipitates with powdered charcoal, and "applying heat to the mixture; and alſo, that the detona"tion, by means of ſulphur, was obſerved to be ſo much "the ſtronger, as the precipitates were more deprived of "their acid *."

Gun-powder is a well known compoſition, conſiſting of nitre, charcoal, and ſulphur †. The proportion of thoſe ingredients has been often varied; but the gun-powder more generally uſed at preſent for the artillery in moſt parts of Europe, conſiſts of about ſix parts of nitre, one of charcoal, and one of ſulphur. Mr. ANTONI, in his excellent work on *gun-powder*, mentions four different ſorts of gun-powder, as the more generally uſed for different purpoſes, viz. 1. The powder for military muſquets; which conſiſts of five parts of nitre, one of charcoal, and one of ſulphur. 2. The powder for cannons; which is made with ſix parts of nitre, one of charcoal, and one of ſulphur. 3. The powder for common ſhooting with a muſquet; which is made with the ſame proportion of ingredients as the preceding, but its grains are ſmaller. 4. The powder uſed for fire-works; which conſiſts of ſeven parts of nitre, one of charcoal, and one of ſulphur.

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* A Treatiſe on Gaſes, chap. xv.

† White gun-powder has been often made, by ſubſtituting *touch-wood*, or the filings of divers ligneous ſubſtances, inſtead of charcoal; but it is by no means ſo good as the common black gun-powder.

In the open air, or confined in a place out of which the air is not exhauſted, gun-powder explodes, when the fire is communicated to any part of it. In proportion as the air, in which the powder is kept, is more rarefied, ſo a greater degree of heat is required to inflame it; and laſtly, in vacuo it does not explode at all.

Dr. PRIESTLEY has found, that gun-powder, when heated, explodes, in every kind of elaſtic fluid, in the ſame manner as it does in common air; even in inflammable air it may be fired without danger; for the inflammable air, provided no reſpirable air is mixed with it, is neither fired, nor loſes its inflammability by it. The Doctor has alſo obſerved, that common air is phlogiſticated by burning a ſmall quantity of gun-powder in it; but other elaſtic fluids are not ſenſibly altered by the like combuſtion. For theſe experiments, Dr. PRIESTLEY uſed to put the gun-powder upon a ſtand in a glaſs-receiver, then exhauſted the common air from it, by means of a good air-pump, and afterwards filled it with the required elaſtic fluid, &c.—Sometimes he introduced the elaſtic fluid and gun-powder into a receiver filled with and inverted in quickſilver; but he remarks, that in this caſe it was not eaſy to convey the gun-powder into the receiver, in the exact quantity that was required †.

" Being deſirous," *ſays Dr.* PRIESTLEY, " of knowing " what kind of air was produced by the exploſion of gun-

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† Exper. and Obſer. vol. i. p. 254 to 257.

" powder, I for that purpoſe mixed equal quantities of brim-
" ſtone and ſalt-petre, both finely pounded, and put them into
" a tall glaſs-veſſel. The production of air was very rapid and
" copious, and ſo highly nitrous, that two meaſures of com-
" mon air, and one of this, occupied the ſpace of 2 ½ mea-
" ſures. Since the produce of air from ſpirit of nitre and
" charcoal is the very ſame with this, viz. nitrous air; it
" cannot be doubted, but that nitrous air is alſo produced
" in the exploſion of gun-powder, which is compoſed of
" thoſe ingredients; the ſpirit of nitre not being deſtroyed,
" or ſo far decompoſed, as that its acid nature is loſt, but
" only entering into the compoſition of this ſpecies of
" air †."

As to the quantity of elaſtic fluid extricated from gunpowder in the act of exploding, the eſtimates of various authors do not agree with each other. This diverſity is principally owing to the various quality and proportion of the materials in the compoſition of the ſpecimens of powder uſed by thoſe perſons, and may be alſo in great meaſure attributed to the difficulty of performing thoſe experiments with accuracy, and to the abſorption of part of the generated elaſtic fluid by the vapour produced by, or the reſiduum remaining after, the combuſtion of gun-powder. Mr. Robins, in his *Principles of Gunnery*, relates ſome of his experiments, which ſhew, that the bulk of the generated elaſtic fluid is about

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† Exper. and Obſer. vol. ii. p. 89.

244 times the bulk of the powder exploded; viz. when that elaſtic fluid is compreſſed by the uſual weight of the atmoſphere, and in a temperate degree of heat; for when this elaſtic fluid is juſt produced, it muſt occupy a much greater ſpace, on account of its being rarefied by the heat of the flame. Mr. ROBINS finding, by experiments, that air, rarefied by ſuch a degree of heat as makes iron barely white-hot, occupies four times the ſpace it did in the uſual temperature of the atmoſphere, ſuppoſes that the elaſtic fluid produced by gun-powder, in its firſt rarefied ſtate, occupies a ſpace at moſt not above 1000 times the bulk of the powder.

The COUNT de SALUCE ſays, that the elaſtic fluid produced by gun-powder, when reduced to the temperature of the atmoſphere, is equal to 222 times the bulk of the powder; which eſtimate he finds to agree with the computations of Meſſrs. HAUKSBEE, AMONTONS, and BELIDOR †.

Dr. INGENHOUSZ makes the following calculation: "A "cubic inch," *ſays he*, "of ſolid gun-powder contains in "weight 442 grains, of which 331½ grains are nitre, 55¼ "charcoal, and as much ſulphur (ſuppoſing the proportion of "the ingredients of the powder to be ſix parts of nitre to "one of charcoal and one of ſulphur): 331½ grains of nitre will produce 552 cubic inches of dephlogiſticated air; "55¼ grains of charcoal will produce about 17 cubic inches

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† See the Miſcellanea, Phil. Mathem. Societatis privatæ Taurinenſis.

" of air, chiefly inflammable, according to the calculation " of Abbé FONTANA *."

From this eaſy calculation, Dr. INGENHOUSZ deduces, that a cubic inch of gun-powder produces at leaſt 569 cubic inches of elaſtic fluid; which, on its firſt production, being rarefied by the flame, occupies about four times that ſpace, viz. 2276 cubic inches.—The Doctor's theory of the exploſion of gun-powder is the following: " Nitre," *ſays he*, yields, " by heat, a ſurprizing quantity of pure dephlogiſticated " air; Charcoal yields, by heat, a conſiderable quantity of " inflammable air. The fire, employed to inflame the gun- " powder, extricates theſe two airs, and ſets fire to them at " the ſame inſtant of their extrication †."

A mixture of inflammable and dephlogiſticated air, after combuſtion, is much reduced in ſize; and the remaining elaſtic fluid is phlogiſticated air: ſo that, according to Dr. INGENHOUSZ's theory, the elaſtic fluid collected after the combuſtion of gun-powder (ſuppoſing that a proper mixture of inflammable and dephlogiſticated air, after combuſtion, is reduced to half the original bulk) ſhould be about 284 times the bulk of the powder; which comes pretty near the reſult of actual experiments: but this elaſtic fluid ſhould be phlogiſticated air; which does not agree with the above-mentioned experiment of Dr. PRIESTLEY, by which it appears, that the ſaid elaſtic fluid is rather nitrous air.—Notwithſtanding the great light lately thrown upon this ſubject, it muſt be confeſſed, that the nature of gun-powder has not been yet thoroughly inveſtigated.

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* Phil. Tranſ. vol. lxix. p. 402.

† Ibid. p. 398.

Fulminating powder, which is commonly made with three parts of nitre, two of fixed alkali, and one of ſulphur, has been alſo imperfectly examined. The more common opinion concerning its exploſion is, that on melting the powder, which muſt neceſſarily precede its exploſion, an *hepar ſulphuris* is formed by the alkali and the ſulphur mixing together; which hepar ſulphuris forms a kind of ſkin or bladder, that confines the air, extricated from the nitre, till the elaſticity of this fluid overcomes the confinement, burſts the ſkin, and occaſions the exploſion. " But I think," *ſays Dr.* INGENHOUSZ, " that the nitre contained in this powder, being " heated, yields its dephlogiſticated air, when the melting " ſulphur yields inflammable air; at the ſame time the ſul- " phur conſtitutes, with the alkaline ſalt, an *hepar ſulphuris*, " which, riſing in tough bubbles, confines this exploſive air " generated. At length, however, the increaſing heat, " which ſet fire to the ſulphur, ſets this exploſive air on fire " alſo; which then following its own nature, explodes " with ſo much the more force, from its having been en- " tangled and confined within the bubbles of hepar ſul- " phuris *."

My reader muſt perceive that theſe lame explanations are far from being convincing.

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* Phil. Tranſ. vol. lxix. p. 404.

Fulminating gold, which explodes with an aſtoniſhing violence, and makes a very ſharp report, has been conſidered as a ſubſtance which would produce a far greater effect than common gun-powder, if it were cheap enough to be uſed for fire-arms; but repeated experiments have ſhewn, that when fulminating gold is confined in a barrel of a piſtol, in a hollow iron-ball, or the like, its effects are much inferior to thoſe of gun-powder; and the reaſon is, becauſe fulminating gold produces an incomparably leſs quantity of elaſtic fluid than gun-powder does. The ſurprizing effects produced by it, when fulminating in the open air, muſt be attributed to the ſudden generation of, and not to the great quantity of elaſtic fluid produced. Mr. BERGMAN ſays, that the elaſtic fluid, generated by fulminating gold, is ſcarcely equal to four times the bulk of the fulminating gold *. He alſo ſays, that half a drachm of fulminating gold, fired in a cloſe veſſel, makes a report hardly audible; and that the elaſtic fluid it generates extinguiſhes flame, is noxious to animals, is not abſorbed by water, nor renders lime water turbid †.—Theſe are the characteriſtic properties of phlogiſticated air.

Dr. BLACK thinks, that fulminating gold derives the property of fulminating from ſome gas, which it received from the alkali uſed for its precipitation.

As to the fulmination of the mercurial precipitates, mentioned above, Mr. BAYEN thinks it to happen in conſequence

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* Opuſcula, vol. ii. p. 162.

† Ibid. p. 144.

of a commotion excited between the mercury and the ſulphur. But the ingenious author of the *treatiſe* on *gaſes*, makes the following remarks upon it: " The detonation," *ſays he*, " of Mr. Bayen's mercurial precipitates, is occaſioned " by the production of an elaſtic fluid; and I think that " this fluid alſo proceeds from the converſion of ſome adhering portion of the acid, in which the mercury had been " diſſolved, into the ſtate of gas (together, probably, with " ſome of the phlogiſton of the metal or ſulphur) by means of " the violent heat and motion excited between the mercury " and the ſulphur in the act of combination, while the mercury is forced from its union with the adhering acid. " For it appears, both from Mr. Bayen's experiments, and " from the analogy of other precipitations, that ſome acid " always adheres to the precipitate; and probably, alſo, " ſome of the alkaline or earthy precipitant."

CHAP. III.

Advantages derived from the ſubject of permanently elaſtic Fluids.

THE improvements that the ſubject of air and other permanently elaſtic fluids has received within theſe laſt ten years, are perhaps of more advantage to mankind, and reflect more honour upon the philoſophers that made them, than thoſe which any other branch of natural philoſophy ever received in the like number of years. The uſe of the air in reſpiration, with the various phenomena concomitant on that great and eſſential function of animal bodies, has employed, for ages, the beſt philoſophical geniuſes; and their various hypotheſes, offered in explanation, rather involved it in obſcurity, than elucidated its real cauſe; but it has been lately explained in an elegant and ſatisfactory manner by Dr. Priestley. The phenomena attending metallic calcinations and reductions, have likewiſe received conſiderable light; and we may venture to aſſert, that very little is wanting in order to underſtand them fully. The method of aſcertaining the air's purity and fitneſs for reſpiration; the diſcovery of dephlogiſticated air; the method of impregnating water with fixed air; and a great many other diſcoveries relating to the ſame ſubject, muſt be certainly allowed to be of the firſt rank, and of great conſequence.

Beſides the immediate uſe to which thoſe capital diſcoveries may be applied, they throw a great light upon many branches of knowledge. Without mentioning any other, it may ſuffice to obſerve, that a great many perplexing proceſſes in chemiſtry have been eaſily explained ſince thoſe diſcoveries have been made; ſeveral proceſſes have been thereby facilitated; and ſeveral new and uſeful ones have been introduced.

Thoſe perſons for whom, when the principles are ſtated, it is unneceſſary to add the minute detail of the divers purpoſes they may ſerve, will at once perceive that this ſubject is of unlimited and eſſential uſe; but for others it may be juſt mentioned, that the preſent ſtate of knowledge relating to air, and other permanently elaſtic fluids, does not furniſh only a new ſet of experiments for a courſe of philoſophical lectures, but furniſhes matter both for uſe and ſpeculation in medicine, œconomy, civil ſociety, mineralogy, agriculture, meteorology, &c.—The medicinal properties of water, impregnated with fixed air, have been in great meaſure aſcertained; and ſuch is uſed. The preſervation of fleſh-meat, by means of fixed air, is of ſingular advantage for the community. The method of aſcertaining the purity of the air of a place, and the manner of ventilating an apartment, are of great uſe for thoſe who are to build a houſe or public edifice in a new place. In ſhort, there is perhaps no ſtation of life for which ſome knowledge of this ſubject is of no uſe. The principal applications of the known properties of permanently elaſtic fluids have been deſcribed; and various other poſſible uſes have been ſufficiently hinted in the preceding pages: ſo that I ſhall omit expatiating farther upon this ſubject, mentioning only, for the ſake of thoſe who are obliged to work in mines, or in general in thoſe places wherein noxious elaſtic fluids are often met with, that they may procure ſufficient means of ſafety at a very cheap rate. Something to this purpoſe has been mentioned towards the beginning of this work; but I think it never enough recommended, ſince it appears, that for want of this ſecurity, ſeveral mines, and other ſubterranean places, are left unexplored on account of the noxious fluids exiſting in them. A bladder-full of common air is ſufficient for the reſpiration of a man during ſeveral minutes; and, if filled with dephlogiſticated air, it will ſerve much longer. Now it is a very eaſy matter to keep by one a bladder filled with common air, at leaſt; which, in caſe any noxious fluid is perceived, by the difficulty of reſpiration, and other ſigns, may be applied to the mouth; and thus equipped, a man may have time enough to eſcape being ſuffocated †. By the ſame means, a perſon may be enabled to deſcend into thoſe wells, and other places, which are abſolutely unexplored by reaſon of the mephitic air they contain.

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† Miners often work in thoſe parts of the mines wherein a candle will not burn; and it is with the greateſt danger of loſing their lives that they go, though for a few minutes, in thoſe ſtill lower places of the mine, in which the air is ſtill more infected, by the greater mixture of noxious fluid.

Bladders to be uſed for this purpoſe ſhould be of the largeſt ſize, and ſhould have a wooden tube, about half an inch in diameter, and three or four inches long, faſtened to their necks. This tube muſt be held in the mouth, and no breath ſhould paſs through the noſe whilſt the air of the bladder is breathed. If a perſon was required to ſtay about half an hour, or longer, in the noxious fluid, he ſhould be provided with four or five, or more, large bladders filled with common air, and ſtopped with a tight cork; and when he finds that the air of one is contaminated, he muſt leave that and take another, and ſo on. Theſe bladders ſhould be filled with a pair of bellows, the nozzle of which muſt be adapted to their wooden tube: but they ſhould not be filled by blowing with the mouth; for in that caſe the air would be partly vitiated.

CHAP.

C H A P. IV.

Conjectures relating to the theory of Fluids permanently elaſtic, and the conſtitution of the Atmoſphere.

THE changes which bodies are obſerved to undergo, in performing experiments on elaſtic fluids, when duly conſidered, afford matter of admiration, and of the profoundeſt contemplation, for a philoſophical mind. In the examination of this ſubject, we ſee ſolid, hard, opaque bodies almoſt entirely reduced into a ſubſtance, which poſſeſſes quite the contrary properties, viz. a fluid tranſparent, inviſible, and whoſe particles, inſtead of their former attraction, now repel each other, and the utmoſt mechanical preſſure is unable to form them again into a ſolid. On the contrary, we obſerve that fluids inviſible and elaſtic loſe at once their aereal form, and are concentrated by the contact of water or ſome other ſubſtance; nay, even two fluids, which by themſelves are inviſible and elaſtic, when mixed together, loſe their elaſticity, and form a ſalt, viz. a body both viſible and tangible. So ſtriking and ſo numerous phenomena could not eſcape being examined by the greateſt philoſophical geniuſes, and hypotheſes being offered for their explanation; but, notwithſtanding the innumerable conjectures offered, and the apparent plauſibility of ſeveral of them, we are yet far from underſtanding this ſubject thoroughly; and, when one is almoſt acquieſcing with a theory, a new fact involves him again in obſcurity.

In conſequence of a ſuſpicion of Sir ISAAC NEWTON *, many ingenious perſons have been led to believe that matter is endowed with an *attractive* and a *repulſive power*; and that there is a limit where, one of theſe oppoſite qualities finiſhing, the other takes place. Thus the particles of a given body attract each other within a certain diſtance; but if by ſome means they are ſeparated aſunder, beyond the ſphere of their attraction, the other power taking place, they then repel each other. Upon this principle they imagine, that when the particles of a ſolid body are ſeparated beyond the limits of their attraction, by menſtruums, by fire, or by other means, they, repelling each other, aſſume the elaſtic form; and thus the air, and other permanently elaſtic fluids, are formed.

A ſuperficial obſerver will find inſtances enough, which apparently confirm this principle; but when the real facts are duly examined, and when we reflect upon the known laws of nature, it ſeems impoſſible to allow the validity of ſuch an hypotheſis. If it be allowed that a quantity of matter has any attraction at all, (which cannot be poſſibly denied) it will be impoſſible to conceive how this power, beyond a certain diſtance, ſhould be changed into a repulſion. Both reaſoning and experiments ſhew, that the attractive power decreaſes in proportion to the diſtances;—ſuppoſe that this decrement is not only as the ſquares, but as the cubes, or any other power of the diſtances; in ſhort, that it decreaſes ever ſo faſt; the only conſequence that can be at laſt drawn from ſuch a ſuppoſition is, that at a given diſtance the attraction is very ſmall, or much ſmaller than any given degree of it; but it is impoſſible to deduce from thence that it ſhould ever vaniſh; much leſs that it ſhould be changed into a contrary power, viz. ſhould become repulſion.

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* NEWTON's Optics, quer. 31.

It may be urged, that, notwithſtanding the impoſſibility of demonſtrating this change of attraction into repulſion by mathematical reaſoning, experiments ſhew the certainty of the fact; for we actually ſee that a hard compact body aſſumes the elaſtic or aereal form, when its particles are ſeparated beyond a certain diſtance. But to this is eaſily anſwered, that the particles of a body do not loſe their mutual attraction, and become repulſive of each other, becauſe they are removed beyond the ſphere of their attraction, but becauſe they are either combined with or ſeparated from other ſubſtances, which renders them repulſive of each other, or to which they owe their apparent mutual attraction; and I may venture to ſay, that there is not one inſtance of a body being reduced from a ſolid or attractive into an aereal or elaſtic ſtate, without being either deprived of or combined

with

with other ſubſtances: thus water is raiſed into vapour, when the particles of heat, being interpoſed between the particles of the water, keep them ſeparate: in fact, on the removal of heat, the vapour becomes water again. Marine acid, when heated, produces an elaſtic fluid, becauſe the action of heat ſeparates its acid particles, which are originally repulſive of each other, from the water which attracted them: in fact, when water is admitted to marine acid air, the particles of the latter loſe their aereal form, not becauſe they are brought within their ſphere of attraction, but becauſe the water attracts them more forcibly than they repel each other. In the like manner may the other phenomena be generally explained; for which purpoſe the following principles are neceſſary to be ſtated, viz. that the particles of ſome bodies in nature are repulſive of each other, viz. are elaſtic, like air, heat, the electric fluid, &c.; but others are attractive of each other, as the particles of metals, of earth, &c.; and that neither the former loſe their repulſion, nor the latter their attraction, except when combined with thoſe bodies which have an attraction towards them, ſufficient to overcome the natural attractive or repulſive power exiſting between their own particles.

Our preſent imperfect knowledge of natural bodies, does not admit a proper determination of the number of thoſe bodies which are originally elaſtic, and thoſe which are attractive of their own particles; but it is the opinion of many able philoſophers, that acid, or at leaſt the acid principle, the alkaline principle, air, phlogiſton, light, the electric fluid, &c. are of the former ſort; and that earth and water are of the latter. Thoſe various ſubſtances have different attractions towards each other; and it is in conſequence of thoſe attractions, that, when brought together, the natural attractive or repulſive power of their own particles is diminiſhed, changed, or ſuppreſſed.

Elaſtic fluids have been conſidered as the bonds of union, or the cementing principle of the particles of other matter; ſince it has been often obſerved, that hard ſolid bodies are become looſe and friable by the elaſtic fluid they contained being extracted from them *; and, on the contrary, other very looſe bodies acquire conſiſtency by abſorbing ſome elaſtic fluid: but upon this ground many bodies, not only elaſtic, but fluids or ſolids, may be called the cementing principle of all thoſe bodies to which they have an affinity, and with which they form a compact body. The permanently elaſtic fluids hitherto diſcovered, and of which a pretty diſtinct notion has been acquired, are principally 1. common air; 2. dephlogiſticated air; 3. fixed air; 4. inflammable air; 5. nitrous air; 6. marine acid air; 7. vitriolic acid air; 8. nitrous acid air; and 9. alkaline air. That theſe elaſtic fluids are not all compoſed of the ſame principles, has been ſufficiently aſcertained; but at the ſame time it ſeems very probable, that one, or perhaps more principles, enter

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* The diminiſhed coheſion of the particles of thoſe bodies muſt alſo be in great meaſure attributed to the action of the acids, or of the heat, that has been employed to expel the elaſtic fluids from them.

into the compoſition of many ſorts of elaſtic fluid. Thus, excepting the alkaline air, the other elaſtic fluids ſeem all to contain a greater or leſs quantity of acid in their compoſition. Indeed, no acid has been obtained from any decompoſition of inflammable air; but the converſion of marine acid air into an inflammable elaſtic fluid, ſuggeſts the poſſibility of ſome acid being contained in inflammable air, though perhaps too intimately combined with the other components of that elaſtic fluid; ſo that we cannot detach it by any known means.—The production of inflammable air by means of alkalies, or from metals by means of heat, offers a great objection to this ſuppoſition; but, as there are various ſorts of inflammable air, it may be that ſome of them may at leaſt exiſt without the neceſſity of containing any acid. As to dephlogiſticated air, an acid ſeems to enter into its compoſition, ſince nitre is found to have loſt all its acid part by the dephlogiſticated air being extracted from it; and, from analogy, common air may have an acid alſo for one of its conſtituent principles, ſince common air has been conſidered to have been originally dephlogiſticated air, or to be depraved dephlogiſticated air, to which a conſiderable quantity of phlogiſton has been afterwards added. The formation of nitre, for which the contact of air ſeems to be neceſſary, contributes to confirm the ſuppoſition of the exiſtence of an acid in reſpirable air. Mr. Lavoisier ſuſpects not that the nitrous acid is a conſtituent principle of air; but that, on the contrary, pure reſpirable air is a conſtituent part of nitrous acid. Theſe conſiderations gradually lead us to farther and farther contemplations; and, if Mr. Lavoisier's conjecture is true, we may ſuſpect that reſpirable air is a conſtituent principle of the other acids alſo. But hitherto no other acid has been indiſputably converted into reſpirable air *.

The inflammable principle, though in various quantities, ſeems to enter into the compoſition of every elaſtic fluid. The other conſtituent principles of thoſe fluids are evidently leſs general; ſuch are the acid principle, earth, alkali, &c. But as the conjectures relating to the quantities and modifications of thoſe principles, when compoſing elaſtic fluids, have been ſufficiently examined in the preceding Part, I ſhall omit to make any farther mention of them †.

Beſides thoſe principles, the exiſtence of which in permanently elaſtic fluids has been ſufficiently proved, it is highly probable

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* The following experiment, related by Mr. Macquer, ſhews a great approximation to it. "I introduced," *ſays he*, "a lighted taper into a receiver filled "with vapours of highly-concentrated marine acid, through a tubulated aperture. The flame of this taper, which was before contracted, white, and "almoſt without ſmoke, now became long, pointed, yellow, and ſmoking, like "the flame of burning turpentine. But the moſt remarkable circumſtance "was, that the flame ſubſiſted a *much longer time*, than when the taper was introduced into the ſame receiver filled with pure air."

† It has been ſuſpected, that all the permanently elaſtic fluids are nothing more than common air overcharged with different ſubſtances, which render it ſo different from what it was before; and the reſiduum left by many elaſtic fluids, after being agitated in water, ſeems to countenance the ſuſpicion: but the ſmallneſs of that very reſiduum, which in ſome caſes is next to nothing, and various other conſiderations, render it very little, if at all, probable.

probable that many other ſubſtances enter into their compoſition; as the electric fluid, the matter of light, and others of which we have no diſtinct notion. Their preſence may be even neceſſary for their exiſtence; and perhaps ſeveral hitherto unexplained properties of thoſe fluids may depend upon them.

The real conſtitution of the atmoſphere, notwithſtanding the innumerable experiments hitherto made, and the advanced ſtate of the ſubject, is yet a matter much controverted, and far from being thoroughly underſtood. The principal queſtion concerning it is, whether the atmoſpherical elaſtic fluid conſiſts of one elaſtic fluid, which by various proceſſes may be altered; or is it a mixture of many permanently elaſtic fluids, as of fixed air, phlogiſticated, and dephlogiſticated air? Upon the whole, the experiments and obſervations which relate to it, ſeem to afford no proper deciſion of this queſtion. If we conſider that fixed, inflammable, and phlogiſticated air, are continually produced from innumerable proceſſes, both natural and artificial, and that thoſe fluids are unavoidably mixed with the common air, it ſeems that a mixture of thoſe fluids ſhould exiſt in the atmoſphere; but, as the air is at the ſame time expoſed to various purifying influences, (as the agitation of water in it, by winds and other means, the vegetation of plants, and probably many other unknown ones) the fixed air, and other elaſtic fluids, in it are moſt likely ſeparated from it; and the air, upon the whole, may be ſuppoſed to remain pretty nearly of the ſame quality. At ſome particular ſeaſons, when the production of the impure fluids exceeds the action of the purifying means, the air may be over-charged with thoſe fluids; or, in the contrary caſe, it may be more than uſually pure: but in a ſhort time the equilibrium may be reſtored.

Mr. LAVOISIER imagines, that in the atmoſpheric fluid there is not above one quarter of pure air; and that the reſt is noxious fluid. But is this pure air chemically combined, or only intermixed with the noxious fluid?—Since the mixture of phlogiſticated and dephlogiſticated air, or of fixed and dephlogiſticated air, is not attended with any ſenſible heat or diminution of bulk, which are the concomitant and characteriſtic phenomena of chemical combination; it ſeems more probable, that the pure and impure parts of the atmoſphere are only intermixed together; and their ſeparation, which would ariſe from their different ſpecific gravities, is prevented by the continual agitation of the atmoſphere. But how happens it then that this ſeparation does not take place when a quantity of air is confined in a place without agitation?—Boiled water, expoſed to the atmoſphere, ſeparates pure air from it; quick-lime, by the like expoſure, acquires fixed air, &c. But are thoſe elaſtic fluids ſimply filtrated from the atmoſpherical air, or ſeparated from it by a chemical decompoſition, or are they compoſed from a mixture of the atmoſpherical air with ſomething elſe exiſting in thoſe bodies that are expoſed to it?—My reader muſt perceive, that theſe intricate queſtions are not eaſily anſwerable. In the preceding Part of this work, eſpecially in the chapters on common and dephlogiſticated air, many obſervations have been mentioned, which throw great light upon this ſubject; but ſtill many other experiments muſt be made, in order to aſcertain the various facts upon which the general theory of the atmoſphere, and of all the other permanently elaſtic fluids, muſt be eſtabliſhed.

EXPERIMENTS made by the AUTHOR.

CHAP. V.

Experiments on Gun-powder.

IN order to collect the elaſtic fluid, produced by gun-powder in its exploſion, I contrived the following apparatus:—To a large bladder I tied a braſs tube, about half an inch in diameter, and four inches long. The bladder was wet on the outſide only, in order to render it pliable. I then pounded ſome gun-powder, ſuch as is commonly uſed for military muſquets, and, putting as much water to it as was ſufficient to make it into a ſtiff paſte, I formed a ſmall cone or pyramid of it, and placing it upon a round piece of braſs, the diameter of which was ſmaller than the diameter of the braſs tube mentioned above, left it to dry: when this ſmall pyramid of gun-powder was dry, I placed it upon a doubled piece of leather; then, preſſing, as well as I could, all the air out of the bladder, and holding the braſs tube perpendicularly, and ready to be fixed upon the cone of powder, I ſet fire to the latter, and immediately clapped the braſs tube upon it, preſſing the tube pretty hard upon the leather. By this means great part of the cone of gun-powder burned within the braſs tube; and the elaſtic fluid, produced by it, entered the bladder. Now, as ſoon as the combuſtion of the powder was over, which did not take up more than two or three ſeconds, I preſſed the neck of the bladder, in order to hinder the elaſtic fluid contained in it, both from eſcaping, and alſo from coming into contact with the coaly reſiduum of the gun-powder; and plunged the braſs tube in water, becauſe this tube was become ſo hot that I could not hold it any longer. This done, I transferred the generated elaſtic fluid from the bladder into a glaſs receiver filled with and inverted in water, in order to examine its nature. Now, with this elaſtic fluid, which was about 12 or 14 cubic inches, there could not be mixed above two inches of common air, viz. that contained in the braſs tube; and which common air was, no doubt, partly expelled, and partly phlogiſticated by the gun-powder, which was actually burning when the braſs tube was put upon it: ſo that the elaſtic fluid thus obtained from gun-powder, may be conſidered as very little, if at all, altered by the mixture of common air.—I then proceeded to examine it.

When firſt transferred into the glaſs receiver, this elaſtic fluid had a whitiſh and turbid appearance; but it became clear in a few minutes time. Lime-water being admitted to ſome of it, became turbid, and a precipitation of the lime took place, which indicated the preſence of fixed air; and, in order to obſerve the quantity of this fluid in it, I introduced two meaſures of it into a glaſs tube, and agitated it in water. In about two minutes time, about half a meaſure diſappeared; which ſhewed, that one fourth part of the elaſtic fluid produced by gun-powder is fixed air. After having ſeparated, by agitation in water, all the fixed air contained in ſome of the elaſtic fluid obtained from gun-powder, I examined the remainder, and found that it extinguiſhed flame; it was not abſorbed by water; nor ſenſibly diminiſhed by nitrous air; it was therefore phlogiſticated air. From all which it appears, that the elaſtic fluid, extricated from gun-powder, conſiſts of three parts phlogiſticated air, and at leaſt one part fixed air: I ſay at leaſt one part of fixed air, becauſe ſome of the fixed air contained in it, and which was not taken into account, muſt have been abſorbed by the water of the tub, on its being firſt transferred from the bladder to the glaſs receiver, and alſo by its ſtanding in it. That the elaſtic fluid of gun-powder has nothing of the nitrous, appeared from its not diminiſhing common air, nor having the leaſt ſmell of nitrous acid. Indeed it has very little ſmell, if any at all, and that ſeems to be rather ſulphurous.

Theſe experiments were repeated with the ſame ſort of gun-powder, and once more with another ſort of powder; but the reſults were like the former. Dr. PRIESTLEY, finding that the elaſtic fluid produced by a mixture of equal parts of ſulphur and nitre, was nitrous air, is led to conjecture that the elaſtic fluid produced by gun-powder is alſo of the ſame nature; but the above-mentioned experiments ſhew the contrary. However, willing to aſcertain myſelf, that no miſtake had happened in my experiments, and alſo deſirous to know by what mixture of the ingredients of gun-powder, fixed air, or nitrous air, was produced, I repeated Dr. PRIESTLEY's experiment, viz. put a mixture of equal parts of nitre, and flowers of ſulphur, into a glaſs tube, which was cloſed at one end; and to its other end I tied a bladder, out of which the air had been carefully preſſed; then, heating the tube ſo as to melt the contents, a quantity of elaſtic fluid was produced, which entered the bladder; and being tried, was found to be nitrous air; and being mixed with common air, it gave I, I. 1. 5. After this, I made ſeveral mixtures of nitre and charcoal, in various proportions, and, putting them one by one into a ſmall piece of braſs tube, treated them in the very ſame manner as I had done the cone of gun-powder, as above related, *viz.* ſet fire to them, and immediately put the braſs tube, with the bladder upon it, in order to catch the produced elaſtic fluid. The compoſition of five parts of nitre, and one of charcoal, produced the ſame ſort of elaſtic fluid as gun-powder, viz. a mixture of phlogiſticated and fixed air; but it ſeemed that the quantity of fixed air in it was rather leſs than a quarter of the whole. The other compoſitions, with different proportions of nitre and charcoal, gave nearly the ſame reſults, only the quantity of fixed air was more in ſome than in others.

We ſee from this, that nitre, with ſulphur, will yield nitrous air; and a mixture of phlogiſticated and fixed air when deflagrated with charcoal. That nitre, which contains dephlogiſticated air, ſhould produce phlogiſticated air when deflagrated with charcoal, is natural enough, ſince the charcoal gives the phlogiſton, which phlogiſticates the pure air extricated from the nitre; but it ſeems very extraordinary that it ſhould not give alſo phlogiſticated air when deflagrated with ſulphur, which ſubſtance does alſo contain phlogiſton. The only ingredient which can occaſion that difference, ſeems to be the vitriolic acid of the ſulphur. Perhaps the ſulphur, being in part decompoſed, its vitriolic acid acts upon the nitre, and diſlodges the nitrous acid from it; which acid, joining itſelf to the phlogiſton of the ſulphur, forms the nitrous air.

The fixed air, produced by gun-powder, ſeems not to be entirely produced by the charcoal; becauſe a quantity of charcoal, equal to that which enters into the compoſition

of

of a quantity of gun-powder, when by itſelf, does not yield, by any known means, as much fixed air as is produced by the gun-powder into the compoſition of which that quantity of charcoal entered. I made a compoſition of three parts of nitre, one of ſulphur, and one of an impalpable powder of copper †; which, in fact, was gun-powder, ſaving only that the powder of copper performed the office of charcoal in it. This compoſition being treated in the ſame manner as thoſe mentioned above, was found to produce, when inflamed, about as much elaſtic fluid as common gun-powder. This elaſtic fluid conſiſted of fixed and phlogiſticated air; though of the former there was not above one tenth part, which is a quantity conſiderably ſmaller than that found in the elaſtic fluid produced by common gun-powder.

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† This impalpable powder of copper, by the contact of an ignited body, takes fire, and burns like tinder in the open air.

CHAP.

C H A P. VI.

Experiments and Obſervations relating to Inflammable and Fixed Air.

IN the ſecond Part of this work, we deſcribed Dr. INGENHOUSZ's piſtol for inflammable air, or, more properly, for to fire a mixture of inflammable and reſpirable air in any required proportion. In the common inflammable air-piſtols, the inflammable air is introduced by putting the mouth of the piſtol upon the mouth of a bottle containing the inflammable air; by which means ſome of the inflammable air aſcends into the piſtol, and mixes with the common air contained in it. In this caſe it is impoſſible to know the proportion of the inflammable to the common air contained in the piſtol. If this piſtol was firſt filled with water, a mixture of inflammable and common air, or inflammable and dephlogiſticated air, in any given proportion, might eaſily be introduced in it, in the ſame manner as an elaſtic fluid is transferred from one veſſel into another in water; but it has been commonly believed, that when the inſide of the piſtol had been wet with water, it was impoſſible to ſend the electric ſpark through it in order to fire the inflammable air. For this reaſon, Dr. INGENHOUSZ, and lately, in a different way, Mr. NAIRNE, have contrived piſtols into which the given mixture of inflammable and reſpirable air might be introduced, without the neceſſity of firſt filling the piſtol with water. The complicated conſtruction of thoſe piſtols, the multiplicity of apparatus belonging to them, and their being eaſily put out of order, have hindered ſeveral perſons from repeating the experiments relating to the inflammability of inflammable air, when mixed with different proportions of reſpirable air: but the following obſervation will render this practice very eaſy.

I have, ere long, obſerved, and have mentioned it to ſeveral perſons, that the common inflammable air-piſtols may be firſt filled with water, in order to fill them with the required mixture of inflammable and reſpirable air, which may afterwards be fired by means of electricity; only in this caſe the diſcharge of a ſmall electric jar ſhould be uſed inſtead of the ſmall ſpark of an *electrophorus*, or of a ſmall *prime conductor*, as is commonly practiſed. The little moiſture which remains upon the ſealing-waxed-piece within the piſtol, will conduct the ſmall quantity of electricity that is communicated by a ſmall ſpark, and will conſequently prevent a ſpark to happen within the piſtol; but it is far from being ſufficient to conduct the diſcharge of a jar all at once. Indeed, theſe common piſtols are often made with a very ſmall ſealing-waxed-part within, which, eſpecially when covered with a little moiſture, will often conduct the diſcharge of a ſmall jar; and they are often, alſo, too weak to ſuſtain the exploſion of a mixture of inflammable and dephlogiſticated air: for which reaſons I have made one in the following manner, which is very eaſily conſtructed, though not eſſentially different from the common ones.

It conſiſts of a braſs tube, about one inch in diameter, and ſix inches long; to one extremity of which a perforated piece of wood, about one inch and a half long, is cemented, and ſecured alſo with two ſhort pins, which paſs through the braſs. A braſs wire, about four inches long, is covered, except its ends, firſt with ſealing-wax, then with ſilk, and afterwards with ſealing-wax again. This wire is cemented into the perforation of the piece of wood, ſo as to project about two inches within the tube, and the reſt on the outſide of it; and its extremity, within the tube, is bent ſo as to come within about one tenth of an inch of the ſide of the braſs tube.—When I want to uſe this piſtol, I fill it with water, and invert it in a tub or baſon of water; then make the required mixture of inflammable and reſpirable air in another veſſel, by putting into it a proper number of meaſures of the former, and a proportionate number of meaſures of the latter; then I introduce this mixture into the piſtol, and ſtop it either with a cork or with a leaden bullet wrapped in cotton. This done, I take the piſtol out of the water, wiping the outſide of it; and, in order to diſcharge it, give it a ſpark with a charged electrical jar, after the uſual manner, which will effectually fire the inflammable air, &c.

The mixture of inflammable and reſpirable air might be made immediately into the piſtol; but for that purpoſe it is neceſſary to have a ſmall meaſuring phial, &c.

In a courſe of experiments, which I made ſome time ago with a view to another ſubject of philoſophy, I had frequent occaſion to obſerve, that a mixture of inflammable and common air often loſt its inflammability; ſometimes it was weakened; and more than once, having examined this mixture when it had loſt its inflammability, I found it changed into mere phlogiſticated air. I am far from underſtanding the cauſe of this remarkable and inconſtant change; yet it may be not improper to recite the particulars relating to it, ſince others may have met with the like phenomena; and probably, by a compariſon of obſervations and circumſtances, the real cauſe may be aſcertained.

I generally took common two-ounce phials, at the bottom of which I made a ſmall hole, and cemented a wire into it, which might project about one inch within the bottle; then I filled the bottle with mercury, and afterwards diſplaced the mercury by a mixture of inflammable and common air in various proportions; though in general the mixture conſiſted of two thirds common air, and one third inflammable air. This done, the phial was ſtopped with a very tight cork, through which a wire paſſed, which, projecting within the phial, came very near the extremity of the other wire that paſſed through the bottom of the phial. In this manner I uſed to fill many phials; and, after keeping

them

them various lengths of time, I fired them, by directing an electric ſpark from the wire cemented to the bottom, to that cemented into the cork; which occaſioned the exploſion, and drove the cork with violence out of the phial. The remarkable particular is, that ſometimes no exploſion happened, even when the diſcharge of a pretty large jar was ſent through ſome of theſe bottles; and when afterwards they were opened, and the flame of a candle was preſented to their mouths, the elaſtic fluid in them generally took fire, and burned like a mixture of very little inflammable air, and a great deal of common air; but ſometimes it did not take fire at all; and, by every trial, it appeared to be phlogiſticated air. This change ſometimes took place in leſs than twenty-four hours; ſometimes not before three or four days; but ſome of thoſe bottles, filled with a mixture of inflammable and common air, after being kept above a week, did explode as well as others that had been juſt made. In the preparation of thoſe bottles, I took all the poſſible precaution to ſtop them accurately; and ſome of them were even kept under water, from the time they were prepared, till they were fired: but I muſt acknowledge, that I could never underſtand the cauſe of this remarkable tranſmutation of inflammable air, any more than conjectures unſupported by deciſive experiments.

In reſpect to fixed air, I have nothing more to ſuggeſt to my reader, beſides an eaſy method of impregnating water with it, in caſe that Dr. Nooth's glaſs apparatus could not be procured, or not conveniently managed, as is the caſe on board of veſſels.

The apparatus for this purpoſe, conſiſts of two or three common quart bottles, and two bladders. Each of the bladders muſt have a ſmall wooden tube, about four inches long, and a quarter of an inch in diameter, faſtened to its neck; and the bottles muſt be furniſhed each with a perforated cork. Into one of theſe bottles the materials for the production of fixed air muſt be put, viz. chalk, or powder of marble, and the diluted oil of vitriol, ſo as to fill about half the bottle; then the perforated cork is put upon it, and immediately one of the bladders is fixed upon the bottle, viz. by thruſting its wooden tube into the perforation of the cork.—Care muſt be taken to compreſs the bladder, in order to exclude the common air from it, before it be adapted to the bottle. The generated fixed air will now enter the bladder, ſwelling it; and when the bladder is almoſt entirely diſtended, it muſt be removed, and muſt be fixed upon one of the other bottles, which is previouſly filled, though not entirely, with the water that is required to be impregnated with fixed air; then, preſſing the bladder with one hand, and with the other ſhaking the bottle, the water contained in it will be ſpeedily impregnated with fixed air, which, both on account of its ſpecific gravity, and of the preſſure made upon the bladder, deſcends from the bladder into the bottle containing the water. As ſoon as the firſt bladder is removed from the bottle containing the chalk, &c. the other bladder muſt be fixed upon it, that no fixed air might be loſt. The third bottle is alſo to be made about three quarters full of water, which may be impregnated with fixed air after the ſame manner, whilſt the water of the other bottle, being impregnated, is uſed for the required purpoſe.

The bladders, in general, give no bad taſte to the water, eſpecially when they have been long uſed; but ſometimes they impart a ſenſible nauſeous taſte or ſmell to the water: for which reaſon, large elaſtic gum-bottles, which now may be had at a very moderate price, may be ſubſtituted inſtead of the bladders.—The common air, which remains over the water in the bottles, gives no hindrance to this proceſs, ſince the water will not abſorb, or at leaſt abſorbs an inconſiderable quantity of it.

CHAP.

CHAP. VII.

Experiments and Obſervations on Plants.

SINCE the publication of Dr. INGENHOUSZ's work, relating to the action of plants on the atmoſpherical fluid, plants, flowers, fruit, &c. have been, by various perſons, ſuſpected as the moſt dangerous things to be kept in an apartment; having been ſhewn by the Doctor, that a flower, or a few French beans, or, in ſhort, that every freſh vegetable ſubſtance more or leſs contaminated the air, to ſuch a degree as to render it quite noxious to animals. The freſh leaves only of plants, inſtead of contaminating, purified the air, when expoſed to the direct rays of the ſun; but, when in the ſhade, and all other freſh vegetable ſubſtances in any ſituation, contaminated the air. When the leaves of plants were put in pump-water, and expoſed to the rays of the ſun, ſome dephlogiſticated air was produced, which Dr. INGENHOUSZ aſſerts to be yielded by the leaves, and not by the water. He relates ſome of his experiments, in which air, contaminated by breathing, was mended by a few freſh leaves being kept in it for two or three hours, when the ſun ſhone upon them.

With a view to obſerve thoſe extraordinay properties of plants, I repeated ſeveral of Dr. INGENHOUSZ's experiments; but their reſults did not entirely agree with thoſe of the Doctor. —I found, that by introducing freſh leaves of plants, juſt taken from the plant, into bottles filled with phlogiſticated air, and expoſing them to the bright ſun-ſhine, the phlogiſticated air was ſo little mended, that it could ſcarce be diſtinguiſhed by the nitrous taſte; but it remained ſtill incapable to aſſiſt animal life, and of courſe much leſs fit to aſſiſt combuſtion. Sometimes I could obſerve no melioration at all. Dr. INGENHOUSZ, when he ſays that the leaves of plants, put into phlogiſticated air, purify it, ſeems to think that the melioration is occaſioned by the plants abſorbing the phlogiſticated part of the air, and not by an addition of the dephlogiſticated air of the leaves to the phlogiſticated air of the phial, ſince he does not remark any increaſe of the bulk of elaſtic fluid. This, indeed, appears to be the caſe; but then this ſame obſervation ſeems to ſhew, that the dephlogiſticated air, obtained when the leaves of plants are put in pump-water, and are expoſed to the ſun, proceeds from the water, and not from the leaves. It may be aſked, why pump water, expoſed to the ſun by itſelf, does not yield any elaſtic fluid; but when the leaves of plants are in it, a conſiderable quantity of dephlogiſticated air is produced?—This queſtion is explained by the following experiments: Having filled three glaſs jars with pump-water, I introduced ſome leaves of vine into one, a piece of new green woollen cloth (which had been previouſly well ſoaked in water, in order to expel any air that might adhere to it) into another, and left the third jar without any thing elſe in it beſides the water. Thus prepared, the three jars were expoſed to the ſun, by the action of which, the water of the two jars, one of which contained the leaves, and the other the cloth, yielded about equal quantities of elaſtic fluid, and with the ſame appearances; but in the other jar there was no elaſtic fluid. Upon trial, the elaſtic fluid of the jar with the leaves proved to be dephlogiſticated air; the elaſtic fluid of the other jar was air ſo far phlogiſticated, that it was ſcarcely at all diminiſhed by nitrous air. — It gave I,I. 1,94; whereas common and nitrous air gave I,I. 1,8.—This experiment being repeated, gave the ſame reſults; it appears, therefore, that the elaſtic fluid collected in jars containing pump-water and leaves of plants, or the piece of cloth, is in all probability produced by the water, ſince the cloth cannot be poſſibly ſuppoſed to yield any elaſtic fluid in theſe circumſtances *. The rays of the ſun paſs freely through the jar containing only water; but in thoſe which contain the leaves, or the cloth, or any the like opaque thing, the rays are hindered; and either by the greater heat they cauſe in it, or by their being refracted, or, in ſhort, by ſome other hitherto unknown property of light, they expel the contained

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[*] No elaſtic fluid was collected in the jar with the cloth, when the direct rays of the ſun did not ſhine upon it.

elaſtic fluid from the water contiguous to thoſe opaque ſurfaces.

The great difference between the elaſtic fluid of the jar with the leaves, and the jar with the cloth, ſhews that the leaves imbibe the phlogiſton of the elaſtic fluid, which is, by the action of the ſun, ſeparated from the water next to their ſurfaces; whereas the piece of cloth, being deſtitute of vegetable life, is incapable to produce that effect.

It might be ſuſpected, that as the plants abſorb the phlogiſton of the elaſtic fluid contained in pump-water, the production of the elaſtic fluid is owing to the increaſe of bulk which the ſame muſt acquire in the act of loſing its phlogiſton; it being natural to imagine, that if phlogiſtication diminiſhes the bulk of air, dephlogiſtication muſt produce the contrary effect. But this can either not entirely, or not at all, be the cauſe, ſince then the water with the piece of cloth ought not to produce any elaſtic fluid.

In reſpect to the injury done by freſh plants, flowers, and fruit, upon common air, I have often examined the air of rooms in which a great many flowers and plants were kept, and the air which had been confined with flowers, fruit, &c. in glaſs jars; but have very ſeldom found any difference between it and the ambient air of the ſame time.

It may be obſerved, that perhaps the difference between ſeveral of Dr. INGENHOUSZ's experiments and mine, may be in ſome meaſure attributed to the different nature of the pump-water, of the ſtate of the plants, and to the weather; ſince, in the ſeaſon Dr. INGENHOUSZ performed his experiments, the weather was remarkably clear, and the ſun ſhone very bright, without much interruption of clouds.

CHAP. VIII.

Promiſcuous experiments.

HAVING been informed, by my ingenious friend Mr. KIRWAN, of a diſcovery made, if I remember right, by Mr. ASCHARD, (who found, that phlogiſticated air was purified by being ſent through melted nitre) I was deſirous to try this remarkable experiment. For this purpoſe I took a glaſs tube, about three quarters of an inch in diameter, and about fourteen inches long, and bent it in the ſhape A B C D, fig. 13. Plate III. The lower part of this tube, viz. I B C I, being filled with very pure nitre, I adapted two ſmall bladders, E F, by means of ſmall glaſs tubes and perforated corks, to the extremities, A D, of the bent tube. One of theſe bladders was filled with air phlogiſticated by iron-filings and ſulphur; the other bladder was without any elaſtic fluid, and conſequently compreſſed. Things being thus prepared, the apparatus was ſuſpended by the ſtring A G D over a charcoal fire, and, according as the tube was heated, ſo it was lowered by degrees till the part B C touched the coals. By theſe means the nitre began to be fuſed; and when it was barely melted, I preſſed the bladder E, which contained the phlogiſticated air, ſo as to let the phlogiſticated air paſs ſlowly through the melted nitre in B C, and enter the flaccid bladder F. When the elaſtic fluid had thus paſſed through E to F, I removed the apparatus from over the fire, took off the bladder F, and, examining the elaſtic fluid it contained, found that it ſuffered a conſiderable diminution by nitrous air. It gave II. I. 2,67, and II. II. 3,62; whereas part of the ſame phlogiſticated air, but which had not been paſſed through melted nitre, was not ſenſibly diminiſhed by nitrous air. It appears, therefore, that the phlogiſticated air was evidently purified by being paſſed through melted nitre. This apparent melioration may be partly owing to the mixture of the ſmall quantity of common air, which remained in the tube A B C D; but I do not think that it could occaſion the whole difference.

Dr. PRIESTLEY, in his firſt volume of Experiments and Obſervations on Air, &c. p. 191, remarks, that thoſe kinds of air, which never had been common air, when rendered wholeſome by agitation in water, are more diminiſhed by freſh nitrous air, than common air which has been made noxious, and reſtored by the ſame proceſs.

Several caſes of this ſort have occurred to me in the courſe of my experiments; but it ſeems, that although the reſiduums of nitrous air, inflammable air, &c. if they ſuffer a greater diminution than phlogiſticated and then reſtored common air, yet they are not equally ſuperior to the purified common air in reſpect to the power of aſſiſting animal life; at leaſt I once obſerved, that the reſiduum of nitrous air ſuffered a greater diminution by other nitrous air, than the purified reſiduum of phlogiſticated common air; yet animals were killed much ſooner by the former than by the latter.

In the ſecond Part of this work, we mentioned the method of diſtinguiſhing one ſingle elaſtic fluid from the other; but in order to diſtinguiſh the various ſorts and quantities in a mixture of different elaſtic fluids, it is not practicable to follow always one method. The operation muſt be adapted to the circumſtances, and to the indication ſuggeſted by the materials which have yielded the compound of elaſtic fluids. Indeed, ſometimes it is next to impoſſible to aſcertain the quantities of two or more elaſtic fluids in a compound, by ſeparating them; in which caſe the only practicable method is, to try to imitate that compound, by mixing divers elaſtic fluids in different proportions. Thus, if I find, after ſeveral trials, that by mixing two parts of nitrous air, one of inflammable, and one of dephlogiſticated air, I obtain an elaſtic fluid, which, by all the trials I can make of it, appears to be like a given elaſtic fluid B, I conclude that B is a mixture of two parts of nitrous, one of inflammable, and one of dephlogiſticated air; though this concluſion may be ſubject to conſiderable errors.

The reader muſt have obſerved, in the courſe of this book, the different ways uſed for the ſeparation of one elaſtic fluid from the other; and I make no doubt but the conſideration of their nature and properties will ſuggeſt him many others, applicable to the various circumſtances of his experiments.

ADDITIONS AND ALTERATIONS.

To page 59.

THE ſolution of the perfect metals in acid menſtruums is conſidered as a partly calcination.

To p. 129. Common vitriolic ether may be purified by waſhing it repeatedly in water; for the water will abſorb the worſt part of it, and the remainder will be found as pure as can be got by any means whatever. In this proceſs, the greateſt part of the ether is loſt.—For the other particulars relating to this new method of purifying ether, ſee a paper of the author, in the lxxiſt vol. of the Phil. Tranſ.

To p. 228. Inſtead of the pieces of money as here directed, the figure exhibits a ſmall ſtand, which is certainly the more convenient, if at hand; otherwiſe the pieces of money anſwer ſufficiently well.

To p. 256. Here it is ſaid, that we have no method of obtaining dephlogiſticated from common air; but there ſhould be excepted the purification of common air by water; for which ſee the chapters on air, and on dephlogiſticated air, in the third Part.

To p. 258. The water impregnated with fluor acid air, is alſo congealed by cold; but it requires a much greater degree of cold than the water impregnated with vitriolic acid air. See p. 744.

To p. 296. The uſe of the bottle D, which has ſeveral holes perforated through its glaſs ſtopper, is to put the materials in it which are to produce any elaſtic fluid; and thus prepared, to introduce it under a glaſs receiver filled with and inverted in water.

To p. 362. When various glaſs jars are kept filled with different elaſtic fluids, in order to prevent miſtakes, it is proper to ſtick pieces of paper upon them, with the names of the elaſtic fluids. It is alſo neceſſary to remark, that when various jars are filled with water out of the tub, the ſurface of the water in it naturally ſubſides; in which caſe more water muſt be poured into the tub, ſo as to keep it filled to about one inch above the ſhelf. The ſame remark may be made with reſpect to the tub containing quickſilver.

To p. 415. Charcoal may yield more elaſtic fluid by combuſtion than by mere heating.

To p. 562. I am informed by Dr. PRIESTLEY, who has repeated Mr. FONTANA's experiment mentioned in this page, that animals will not live longer in a quantity of dephlogiſticated air when it ſtands in contact with lime-water, than they will when no lime-water is uſed; therefore, according to this obſervation of the Doctor, 12,000 cubic inches of dephlogiſticated air, which is the quantity obtainable from one pound of nitre, can ſerve for the reſpiration of a perſon only *for about four hours*.

To p. 567. Fig. 8. of plate III. exhibits the inſtrument deſcribed in this and the next page.

When a candle is extinguiſhed by letting it down into fixed air, it often happens that the flame remains over the ſurface of the fixed air, when the extremity of the candle is even at ſome inches diſtance from it; and in that caſe the candle may be lighted again, or rather the flame may be brought again in its place, by only raiſing up the candle along the ſame line. In this caſe, part of the ſmoke, which proceeds from the candle, ſupports the flame over the ſtratum of fixed air.

In regard to the formation of atmoſpheric air, it is as yet unknown whether the whole maſs of it does augment or diminiſh. Several natural proceſſes continually diminiſh it, but ſeveral others produce it; and, among the reſt, the reſiduum of the fixed air, that is continually generated and abſorbed by water, may add to its quantity.

In the ſecond vol. of Mr. BERGMAN's Opuſcula, there is a paſſage relating to dephlogiſticated air, which ſeems to overturn the common theory of it. I have not had time to make any experiments about it; but yet ſuſpect that Mr. BERGMAN's opinion may have been occaſioned by ſome miſtake or other. The paſſage, tranſlated from the Latin, is as follows: "Dephlogiſticated air is uſually called that elaſtic "fluid, which is abſolutely neceſſary for the reſpiration of "animals, and for combuſtion. A certain doſe of phlo-"giſton being joined to it, forms the matter of heat, which "has been demonſtrated by Mr. SCHEELE, by a long ſeries of "experiments, which I have often repeated with ſucceſs. "Having eſtabliſhed this baſis, let us examine the changes "to which it may be ſubject. The pureſt I could obtain "cannot be rendered unfit for reſpiration or combuſtion by "flame, by nitrous air, by electric ſparks, or by any opera-"tion in which phlogiſton is certainly let looſe: however, "it contracts, and at laſt is entirely conſumed, and that in "ſuch manner as to acquire the phlogiſton, and to become "the matter of heat, which penetrates all ſorts of veſſels, "and cannot be confined." He then ſays, that by the burning of a piece of wood, its bulk is contracted; but "the reſi-"duum, which is an eighth, a tenth, and often hardly the "hundredth part of its original volume, conſiſts partly of "fixed air, and partly of air incapable to aſſiſt reſpiration

" and combuſtion ; but which was admitted to it from the " beginning."

The following method of Mr. SCHEELE, to examine the purity of atmoſpherical air, was communicated to me by Mr. KIRWAN :

Mr. SCHEELE conſtructed an eudiometer, conſiſting of a glaſs receiver, which could contain 34 ounces of water, and a glaſs cup containing a mixture of one pound of iron-filings, and an equal weight of flowers of ſulphur moiſtened ; which cup ſtanding upon a glaſs ſupporter, was inſerted in the former receiver, which, when this was in it, could contain 33 ounces of water. To the outſide of the glaſs tube, or receiver, was affixed a ſlip of paper, to the height of a third of the tube, containing 11 diviſions, each correſponding to one ounce of water. This paper was varniſhed over with oil varniſh, to prevent its being ſpoiled by water. The whole then was placed in water, which gradually roſe as the air was diminiſhed. This mixture would ſerve four times before the power of diminiſhing air was loſt. He carefully compared the height of the air therein with the barometer and thermometer, both before and after the experiment ; in eight hours the experiment was compleated. With this inſtrument he examined the goodneſs of the common air in Stockholm every day for a whole year, and found the diminution never to exceed $\frac{10}{33}$, nor fall ſhort of $\frac{8}{33}$; ſo that upon a medium it may be eſtimated at $\frac{9}{33}$. During the months of January and February it was $\frac{9}{33}$. The 23d of March it was $\frac{8}{33}$, though the cold increaſed, and the barometer ſtood higher than before. The 19th of April it was $\frac{10}{33}$, though the barometer and thermometer did not vary, and ſo ſtood till the 21ſt. In May and June it ſtood between $\frac{8}{33}$ and $\frac{9}{33}$. The 30th of July it ſtood at $\frac{10}{33}$. From the 3d to the 15th of September at $\frac{9}{33}$. The 6th of October at $\frac{10}{33}$, during a high ſtorm; but after it ſtood between $\frac{8}{33}$ and $\frac{9}{33}$, till the 4th of November, when it fell to $\frac{8}{33}$, and continued between $\frac{8}{33}$ and $\frac{9}{33}$ to the 20th, when it roſe to $\frac{10}{33}$. The 21ſt it fell to 8, and ſtood between $\frac{8}{33}$ and $\frac{9}{33}$ till the 8th of December, when it roſe to $\frac{9}{33}$; and from thence to the 31ſt it ſtood between $\frac{8}{33}$ and $\frac{9}{33}$.

ERRATA.

Page	Line	for	read
28	2	are principally taken	are taken
60	2	partly	partial
64	8	ſmall	moderate
78	22	which has	which when melted has
86	20	*paracea*	*panacea*
88	7	concentrate	concentrated
134	9	of iron-earth	on iron, of earth
141	12	HEMBERG's	HOMBERG's
152	22	muſt take to	muſt take care to
153	12	of a watch	on a watch
177	23	an equal bottom	equal bottoms
231	laſt	damage	hurt
235	2	but if	if
240	24	bring	being
246	13	originating	originated
246	20	affected	the affected
263	11	As the moſt uſed mineral	As ſome mineral
269	5	about half a	about a
278	11	*To make nitrous acid air*	*To make vitriolic acid air*
296	11	four	three
298	laſt	*b*	L
304	16	13th	14th
304	18	Dr. NORTH	Dr. NOOTH
306	21, 22	always	ſometimes
330	15	In fig. 2. plate III. is	In the ſame figure is alſo
		N. B. After this line, throughout the reſt of the page, the capital letters which refer to the fig. ſhould be ſmall Italicks.	
371	11	combined	combined with
380	8	has	had
386	12	having	having been
423	10	E	D
435	12	fig. 20.	fig. 10.
485	12	whatſoever	whatſoever manner
539	24	lected	collected
567	21	variety	cavity
578	13	novo	nova
655	7	yield	yields
772	11	0,042	0,42
804	laſt	that acid	that acids

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FINIS.

Fig. 1.

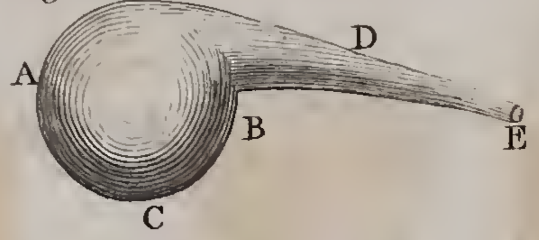
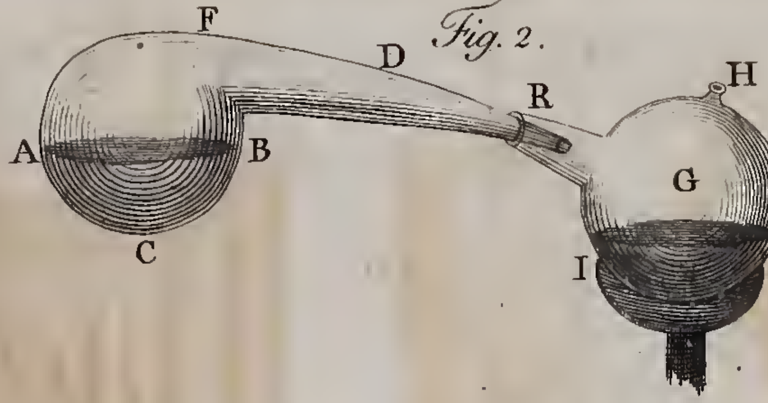


Fig. 2.



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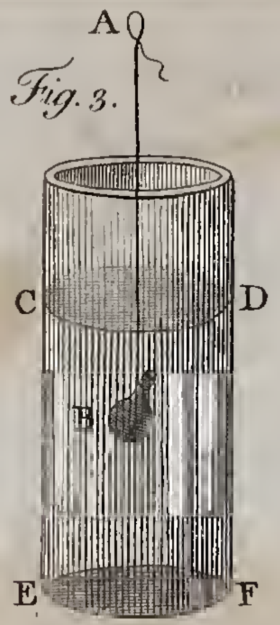

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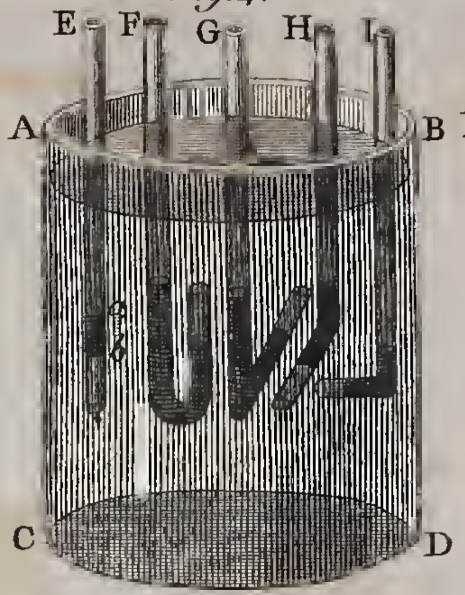

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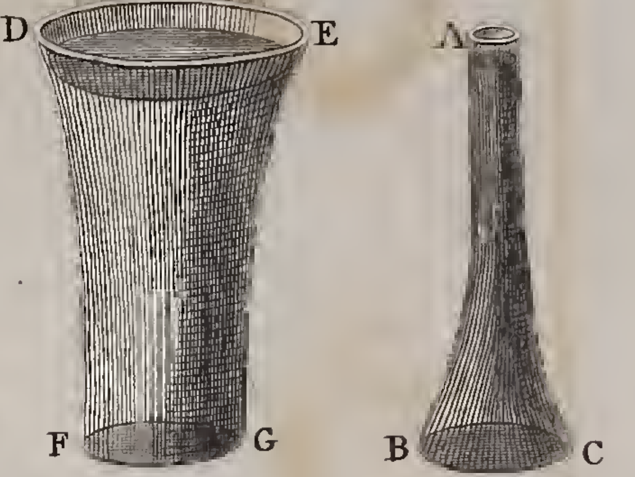

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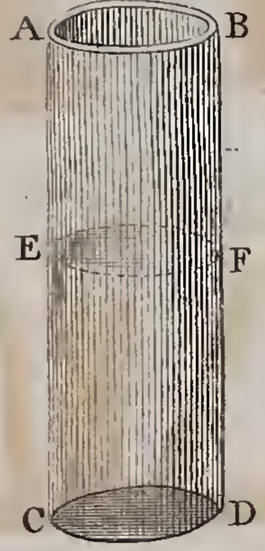
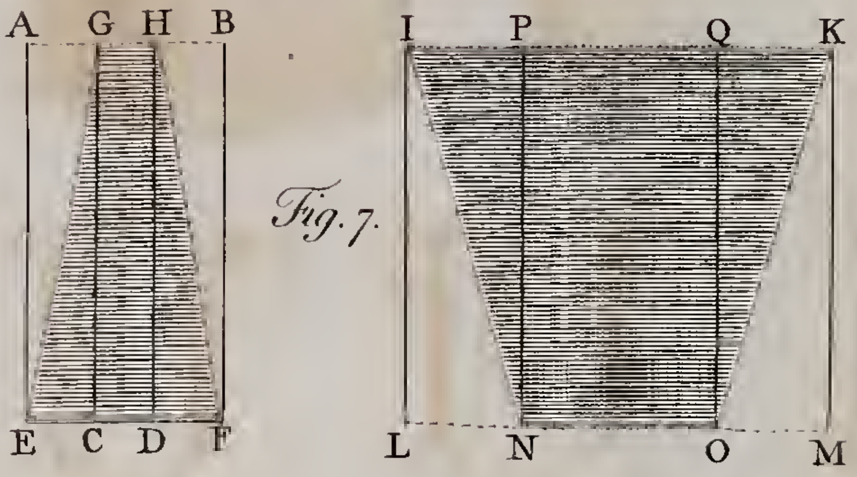


Fig. 7.



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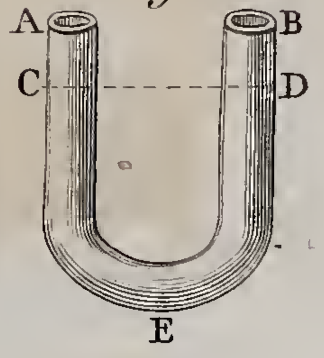

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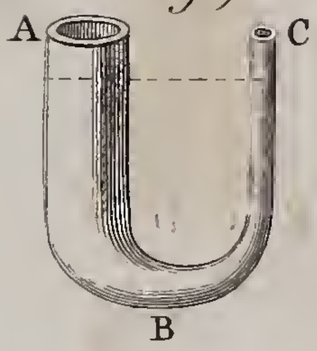

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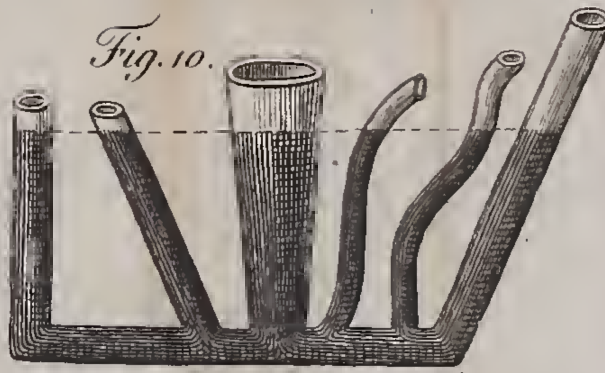

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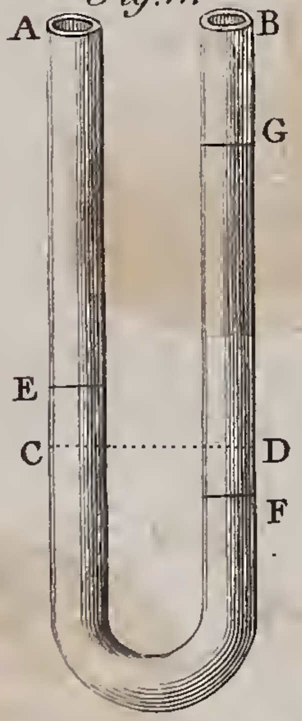
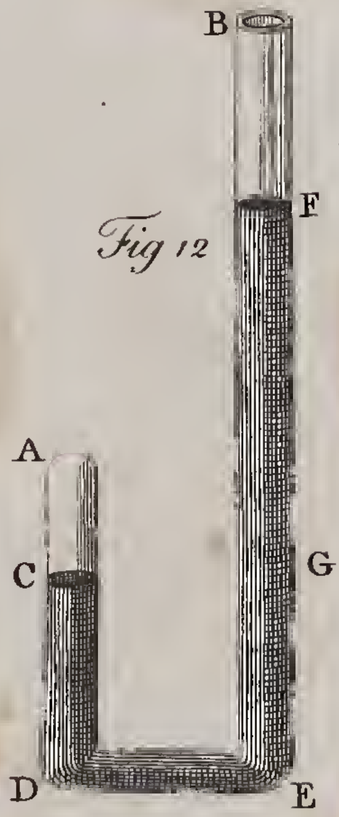


Fig 12



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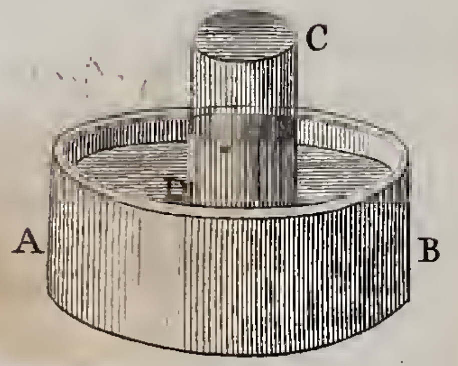

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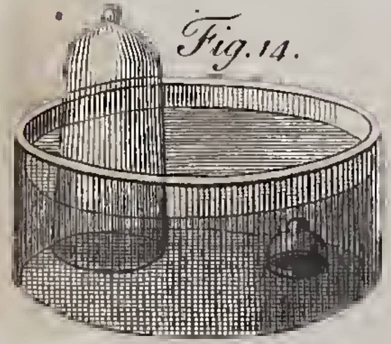

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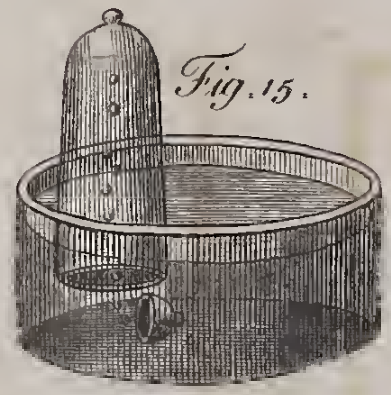

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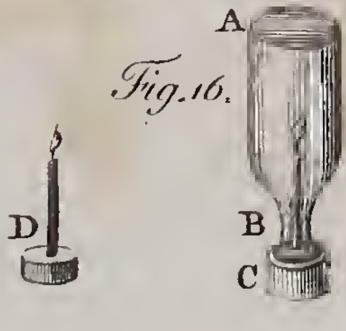

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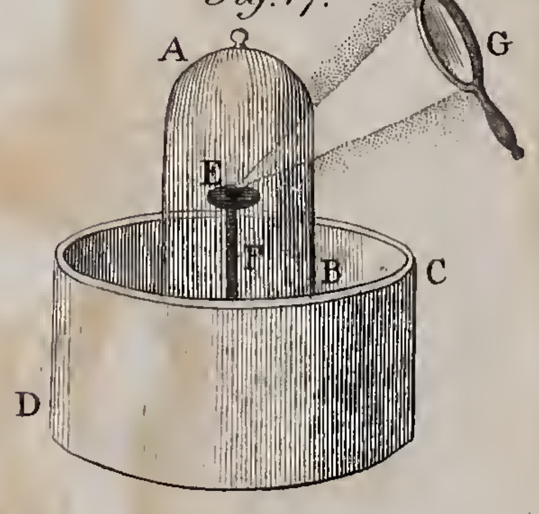

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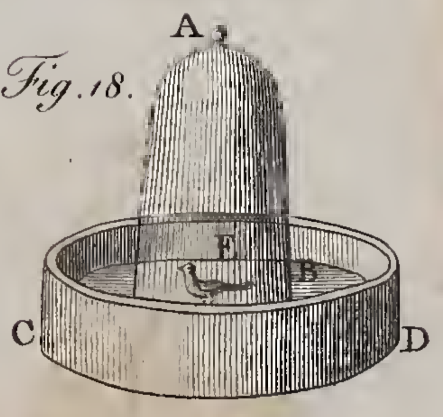

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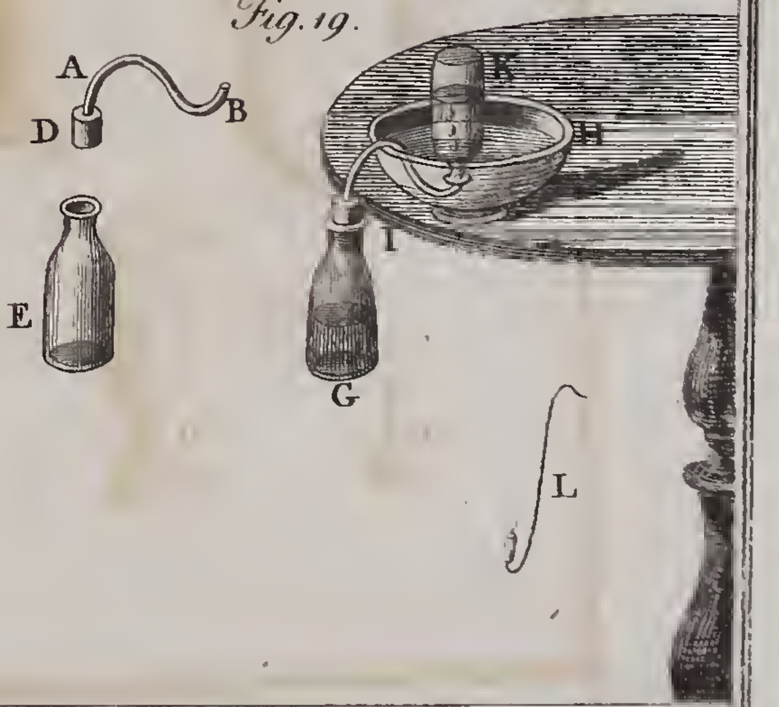

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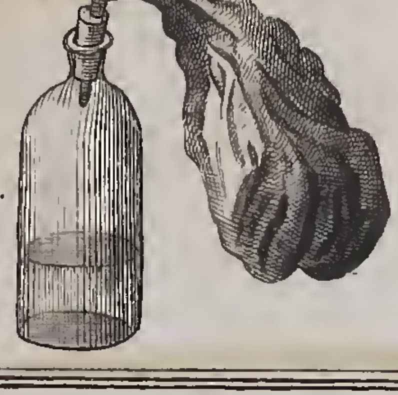

BASIRE SC

PLATE II.

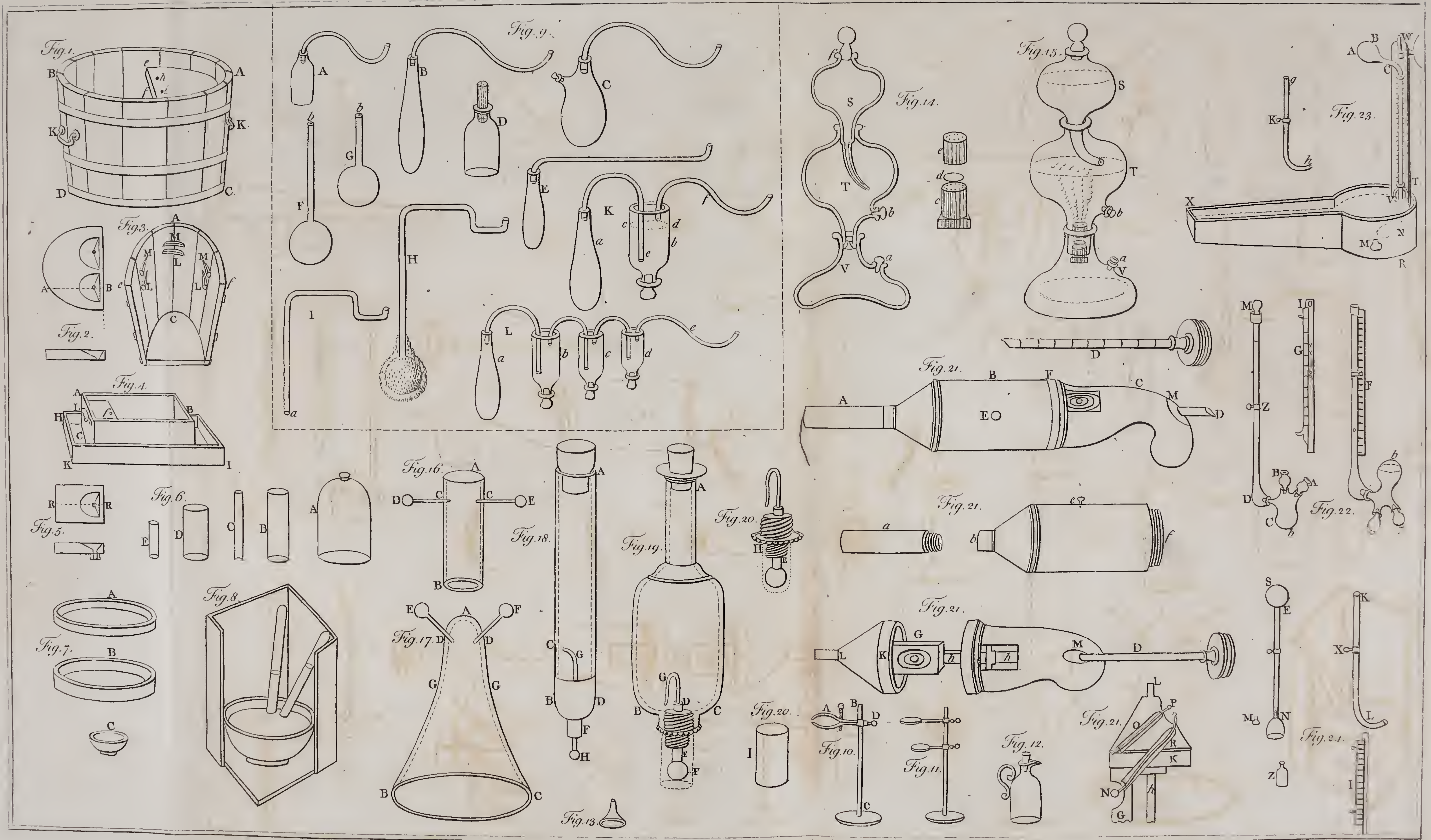

Fig. 1.
A B C D K K e h i
Fig. 2.
Fig. 3.
A M L L L M M C c f
A B
Fig. 4.
A B L H C K I
Fig. 5.
R R
Fig. 6.
A B C D E
Fig. 7.
A B C
Fig. 8.
Fig. 9.
A B C D E F G H I K L a b c d e f
Fig. 10.
A B C D
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
S T V a b f
c d e
Fig. 15.
S T V a b
Fig. 16.
A B C C D E
Fig. 17.
A B C D D E F G G
Fig. 18.
A B C D F G H
Fig. 19.
A B C D E F G
Fig. 20.
H E
Fig. 20.
I
Fig. 21.
A B C D E O F M
D
Fig. 21.
a b e f
Fig. 21.
L K G h h M D
Fig. 21.
L P O R K N G h
Fig. 22.
M I G Z D B A C b F b
Fig. 23.
A B W C T V X M N R g K h
Fig. 24.
S E M N Z K X L I

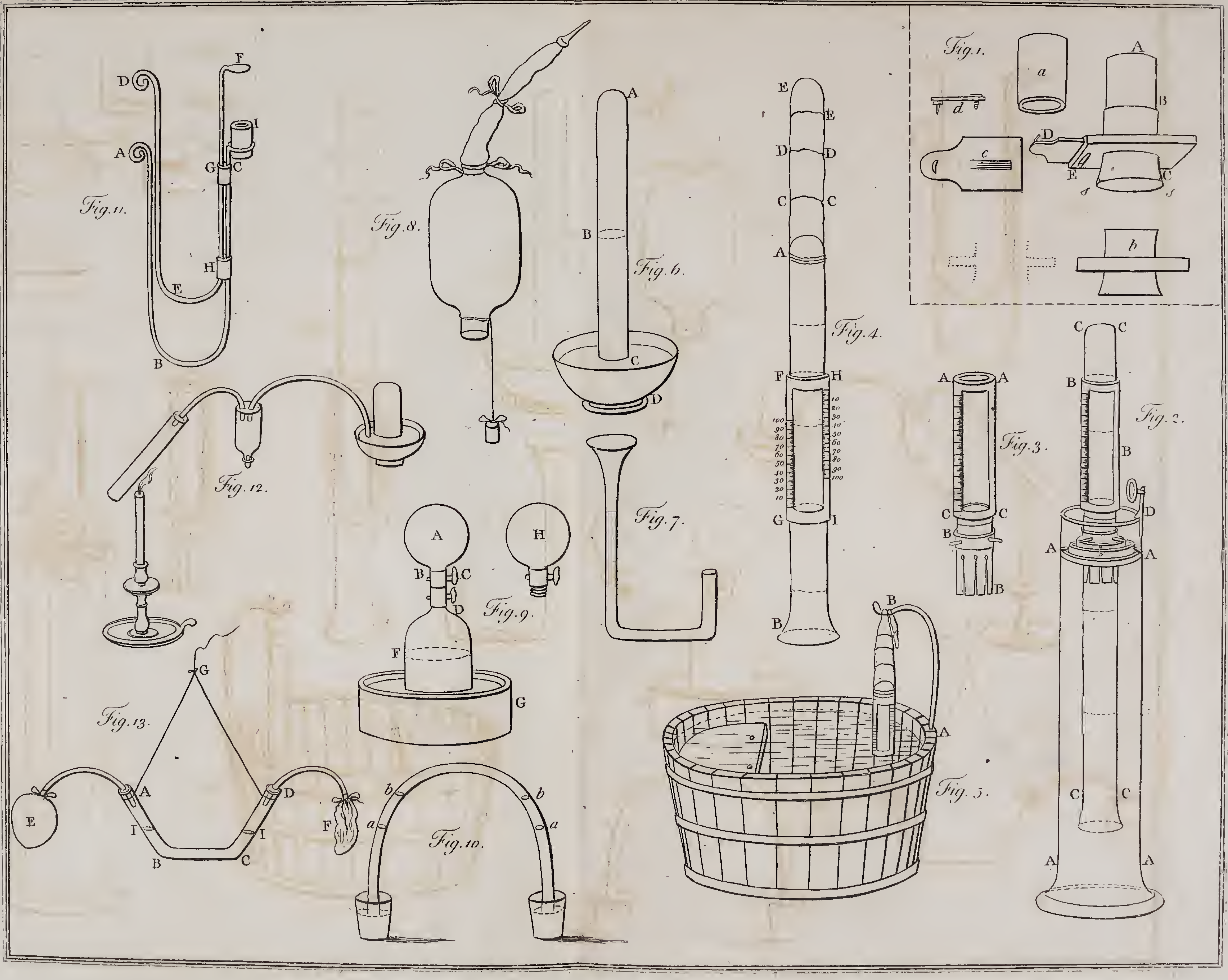
Fig. 1.
a
d
c
b
A
B
D
E
C
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
A
B
C
D
E
F
G
H
I
a
b